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STANDARD ENGINE REPORT ON CURTISS 12-CYLINDER MODEL C-12, GEARED AVIATION ENGINE, RATED AT 400 H. P. AT 2250 REVOLUTIONS PER MINUTE (ENGINE SPEED)

(POWER PLANT SECTION REPORT)

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STANDARD ENGINE REPORT ON CURTISS 12-CYLINDER, MODEL C-12, GEARED AVIATION ENGINE, RATED AT 400 H. P. AT 2,250 REVOLUTIONS PER MINUTE (ENGINE SPEED).

OBJECT OF TEST.

The object of this test was to obtain complete information concerning the design and the performance of the Curtiss 12-cylinder, model C-12, geared aviation engine, rated at 400 horsepower at 2,250 revolutions per minute (engine speed).

SUMMARY OF TEST RESULTS.

Brake horsepower at full throttle, normal speed, 427.4 brake horsepower at 2,250 revolutions per minute (engine speed).

Fuel consumption at normal speed, 0.503 pound per (actual) brake horsepower-hour.

Oil consumption at normal speed, 0.0832 pound per (actual) brake horsepower-hour.

Brake mean effective pressure at normal speed, 131.3 pounds per square inch.

Total weight, dry, 698.0 pounds.

Weight, dry, per normal brake horsepower, 1.633 pounds.

CONCLUSIONS.

The engine on test showed excellent power, developing a higher output per unit of weight than any water-cooled engine heretofore tested by the Engineering Division. The fuel economy is good, but the oil consumption is excessive. A number of features of the design would have to be changed to make the engine suitable for service use.

No definite conclusions are possible as to the reliability of this engine until it has been subjected to a 50-hour test.

DESCRIPTION.

NOTE.—This engine is a redesigned Curtiss Kirkham 12-cylinder engine, which is completely described in Engineering Division report, Serial No. 811. The principal differences are as follows:

Curtiss C-12.	Curtiss Kirkham 12-cylinder.
Detachable en-bloc water jackets...	Cylinder water jackets cast in pairs, integral with upper half of crank case.
Eight crank-shaft bearings (3 inches diameter).	Five crank-shaft bearings (2.5 inches diameter).
One spark plug on each side of cylinder.	Both sparks plugs on intake side of cylinder.
Claudel-Hobson inverted carburetors.	Ball & Ball carburetors in the Vee.
Berkshire magnetos................	Berling magentos.

TYPE.

Name.. Curtiss.
Model.. C-12.
Serial number of engine tested:
  Manufacturer's.................................... No. 4.
  A. S.. No. 94975.
Number of cylinders.................................. 12.
Arrangement.. 60° Vee.
Drive.. Geared.
Cooling.. Water.
Cycle.. Four.
Fuel.. Gasoline.
Tractor pusher....................................... Either.
Adapted to cannon.................................. No.

MANUFACTURER.

Curtiss Aeroplane & Motor Corporation, Garden City, Long Island.

CHARACTERISTIC FEATURES.

Steel cylinder liners with integral combustion chambers, screwed into aluminum head casting; detachable en-bloc aluminum water jackets permitting cooling water in direct contact with sides of cylinder barrel; four separate cam shafts; four directly actuated valves per cylinder; herringbone reduction gears; wet sump; articulated connecting rods; two Claudel-Hobson inverted carburetors and two Berkshire magnetos with provision for battery excitation in fully retarded position.

Crankcase (see figs. 6 and 7):
  Material............................ Aluminum alloy.
  Parted.............................. In horizontal plane passing through centerline of crank shaft.
  Clamped together.................. With small bolts and nuts along parting flange.
  Number of crankshaft bearings..... Eight.
  Type of bearings.................. Plain.
    Material......................... Bronze shell lined with white metal.
  Bearings are carried............... In transverse webs in upper half of crankcase and in bearing caps.
  Bearings are secured............... With four countersunk brass screws for each half of bearing.
  Adjustment of bearings............ None..
  Oil grooves in bearings............ None.
  Accessory gear drive housing....... Bolted to rear of crankcase.
  Engine mounting lugs or flanges—
    Number.......................... Ten.
    Location........................ Five on each side of upper case.
    Type............................ Case is buttressed to form lug.
    Number of bolts in each lug.... One.
  Upper half—
    Type of webs.................... Single.
    Bearing caps—
      Type......................... I beam section.
      Material..................... Aluminum alloy.
      Retained..................... By four studs and nuts. Also have positioning key between studs on the right side.
  Breathers:
    Number.......................... Six.
    Location........................ Inside of Vee at webs Nos. 2, 4, 6.
    Construction.................... Cored passages in crankcase.

Crankcase—Continued.

Oil passages—

From mounting flange through No. 4 web to inside of case supplying oil to main bearings.

From around No. 1 bearing to upper vertical shaft bearing and directly up to the top of crankcase supplying oil for camshafts.

From No. 8 bearing by oil tube to front propeller shaft bearing.

Lower half—

Function	Oil sump.
Webs	None.
Breathers	None.
Compartments	Four.[1]
Oil passages	From sump at each end by oil tube to scavenging pump.

NOTE.—Oil pump is attached in the bottom of the crankcase. There are three oil drain plugs. An oil gage with cork float is on the right side. There are nine cooling fins on the underside in the slipstream from the propeller. The oil pump drive shaft is carried in a bronze bearing at the rear. There is an oil drip pan dividing the main body of the crankcase into two compartments. The oil filler passageway by-passes the drip pan to the oil sump.

Crankshaft (see figure 8):

Type	Integral.
Material	Chrome nickel steel.
Bored	Through journals and crank pins.
Crankshaft gear retained	By three internal keys.
Oil passages in shaft	By oil tubes from main bearings to crank pins.

Reduction gear (see fig. 8):

Ratio (propeller speed to crankshaft speed).	3:5.
Type of gearing	Herringbone.
Gears—	
Material	Chrome nickel steel.
Fastened on shaft	Bolted to integral flanges.
Propeller shaft—	
Material	Chrome nickel steel.
Front bearing	Bronze shell with white metal lining.
Thrust bearing—	
Type	Single row ball bearing.
Adjustment endwise	By shims.
Retained	By threaded nut and lock wire.
Bored	Entire length.
Provision to prevent leakage where shaft passes through case.	By split aluminum ring threaded opposite to direction of rotation.

Propeller hub (see fig. 8):

Material	Steel.
Type	Rear flange integral with propeller shaft. Front flange removable over splines.

Connecting rods (see fig. 9):

Type	Main rods and articulated rods.
Material	Alloy steel.
Section	I beam.
Main rod—	
Big end arrangement	Cap held with four bolts over crankpin.
Type of bearing	Plain.
Material of bearing	Bronze shell lined with white metal.
Bearings are retained in rod	By four brass dowel pins.
Adjustment of crankpin bearing	None.
Small end bearing—	
Type	Bushing.
Material	Bronze.
Retention	Pressed in.
Adjustment	None.
Oil passages in rod	Oil hole in bearing shell registers with hole in crank pin Oil is distributed to hinge pin bushing by two oil tubes. The upper end has two oil holes on upper side.

[1] The four compartments are front sump, rear sump, and upper and lower halves (divided by oil pan).

Connecting rods—Continued.

Articulated rod—

Lower end arrangement	Forked over hinge pin support or lug on main rod.
Lower end bearing—	
Number	Two.
Type	Plain.
Material	Bronze.
Retention	Pressed in.
Adjustment	None.

The hinge pin is held from rotating in its bearing, in the main rod, by a groove in the pin which registers with the bolt holding it in place.

Pistons (see fig. 9):

Type	Trunk.
Material	Aluminum.
Internal ribbing	One concentric rib and one cross rib.
Rings—	
Number	Three.
Type	One-piece peened rings with diagonal gap.
Material	Cast iron.
Location	Above piston pin.
Oil scrapers	One groove above piston pin communicating by six holes to inside of piston.

Piston pins (see fig. 9):

Material	Steel.
Bored	Taper from each end.
Retained in piston	By two snap rings.
Oil holes	Three.

Cylinders (see fig. 10):

Barrel—	
Type	Sleeve, with integral head screwed into cylinder head.
Material	High carbon steel.
Construction	Hydraulic forging, heat treated.
Stiffening ribs (on outside)	Six (annular).
Head—	
Material and construction of valve seats.	Bored in steel cylinder head.
Construction of valve ports	Cored passages in aluminum cylinder head.
Material of valve guides	Cast iron.
Construction	Removable.
Provision for cooling water to reach valve guides and seats.	Cored passages in aluminum cylinder head.
Location and construction of spark plug bosses.	Bronze bushings inserted inside through threaded portion of sleeve. Taper thread on outside.
Water jacket—	
Material	Aluminum alloy.
Construction	Flanged at upper and lower ends.
How fastened	Bolted to cylinder head and to crank case.
Location of water connections—	
Inlet	At bottom of water jacket (exhaust side).
Outlet	To inlet manifolds through cored passages.
Other features	The center of the head of the sleeve carries an integral stud which is drawn up inside the water jacket by a nut. There is a rubber packing ring between the lower flange on the cylinder sleeve and the internal flange on the water jacket.

Drives (see figs. 11 and 17):

Upper vertical shaft—

Construction	Inclined shaft drive gear and magneto drive gear are integral. Vertical shaft gear is keyed to shaft and retained by lock flange.
Bearings	Lower end bearing is bronze. It is pressed in the gear case. Upper end is a ball bearing located in aluminum flange plate.
Lubrication of bearings	Lower end bearing has direct feed from above No. 1 crankshaft bearing.

Inclined shaft—

Construction	Upper and lower gears keyed on the shaft and are retained by nut and cotter pin.
Bearings	Ball bearings at upper and lower ends.
Lubrication	By oil from cam shafts.

Lower vertical shaft—

Construction	Lower vertical shaft gear and worm for gasoline pump are integral with shaft. Oil pump drive shaft drive gear is keyed to shaft.
Bearings	Bronze bushings which are pressed in gear case.
Lubrication	Oil from drip pan and partially from above.

Valves (see fig. 12):

Number per cylinder	Two inlet—two exhaust.
Location	In cylinder head.
Type	Tulip.
Material	Tungsten steel.
Spring collars are retained on valve stem.	By castellated tapered sleeve threaded on the valve stem and cottered to it.
Interchangeable valves	Yes.
Valve springs—	
Number per cylinder	Two.
Type	Concentric coil.
Material	Alloy steel.
Interchangeable	Yes.

Valve gear (see fig. 13):

Cam shafts	Separate inlet and exhaust shaft for each bank.
Material	Low carbon steel.
Construction	Integral forging.
Form of cams	Constant acceleration and retardation.
Boring and oil passage	Counterbored and plugged to form oil passage.
Camshafts interchangeable	Right and left are interchangeable.
Cam shaft housing—	
Material	Aluminum alloy.
Construction	Aluminum casting.
Retained in place	By studs and nuts.
Number and material of cam shaft bearings.	Six supporting brackets of aluminum alloy to each bank of cylinders.

NOTE.—The cam followers are tee shaped yokes, each operating a pair of valves. The stem of the cam follower slides in a bronze guide. The tappet clearance is adjusted by means of a tappet screw in each end of the yoke locked by a clamp screw.

Valve timing adjustment: There are 10 holes in the cam shaft drive gear which is fastened to the inlet cam shaft with 5 studs. One tooth on the cam shaft gear is equivalent to 20° of crank shaft rotation. Rotating the cam shaft gear (disengaged) one bolt hole without moving the crank shaft gives a valve timing adjustment of 4°.

Lubrication system:

Pressure oil pump—

Number	One.
Type	Gear.
Material (gears)	One bronze, one steel.

Lubrication system—Continued.

Scavenging oil pumps—

Number	Two (using a common gear).
Type	Gear.
Material (gears)	Two bronze, one steel.
Strainer—	
Number	One.
Type	Fine mesh screen reinforced against collapse from suction.
Relief valves—	
Number	One.
Type	Spring operated, conical seat.
Location	In lower part of mounting flange of oil pump.
How reached for adjustment	From outside.
How adjusted	By washers in rear of spring.

MAIN PRESSURE CIRCUIT.

The oil is drawn through the screen around the pressure pump, which is situated in the sump reservoir in the bottom of the lower crankcase. The pump is driven by a horizontal shaft from the vertical accessory shaft. The oil is discharged by the pressure pump past the pressure relief valve to the external pressure line. It is taken to a flange connection at the upper half of the crankcase at No. 4 web on the left side. This external pipe connects with the oil mainfold which distributes oil to the eight main bearings. From here oil is led through tubes in the crankshaft to the crankpins and through metering holes lubricates the bearings. There is a direct feed by an oil tube to the hinge pin bearing from the crankpin. The piston pins and cylinder walls receive their lubrication by spray thrown by the cranks. Oil bypasses No. 8 main bearing and is carried by a tube to the front propeller shaft bearing.

AUXILIARY CIRCUIT.

Oil bypasses No. 1 crankshaft bearing bushing and is led through a drilled hole to the bronze bearing for the upper vertical driveshaft. From No. 1 bearing there are passages leading to external tubes which supply the camshafts, the oil going in through one camshaft and returning through the other. A hole at each camshaft journal lubricates the camshaft bearings. There are bypasses from one bearing across to the other to insure positive lubrication. Surplus oil in the cylinder head lubricates the valve stems, cam follower stems, etc. The extra oil in the cylinder head runs down the camshaft drive housing and lubricates the various drives. A baffle plate collects oil and drips it on the reduction gears. Spray from the reduction gears lubricates the thrust ball bearing on the propeller shaft.

SCAVENGING CIRCUIT.

Oil is pumped from the end sumps by scavenging pumps connected to each sump by a tube. Each scavenging pump outlet is a copper tube which carries the oil outside the screen. The oil from the cranks falls on an oil pan partition where it may run to either the forward or rear sump.

AUXILIARY LUBRICATION.

An external connection from the oil pump connects directly to the gasoline pump.

MISCELLANEOUS.

The oil reservoir is equipped with an oil gage which is calibrated in gallons. The pressure gage connection and the thermometer connection are at the mounting flange

on the left side at No. 4 web. The oil filler on the right side bypasses the drip pan to the oil reservoir. There is no provision for refilling the sump while in flight.

COOLING SYSTEM.

Water pump:	
Number	One.
Type	Centrifugal with double shrouded vanes.
Material (impeller and casing)	Aluminum alloy.
Location	Lower part of gear case.
Stuffing box	A splined bronze bushing is screwed on the notched ball bearing housing. To tighten the gland the ball bearing housing is turned as if tightening a left-handed nut.

MAIN CIRCULATION SYSTEM.

The water leaves the pump by two outlets and connects with tapered inlet manifolds which deliver water to the lowest point of the water jacket in each cylinder. The water surrounds the cylinder sleeves and passes through drilled holes to the cylinder head. It circulates around the ports and passes to the outlet water manifolds through cored holes in the intake manifolds. From here it passes to the radiator. A drain cock is screwed in the pump cover casting.

Intake manifolds (see fig. 14):	
Number	Four.
Type	Fan-shaped.
Materials	Aluminum alloy.
Construction	Castings with cored holes for water outlets.
Type of flanges	One piece.
Manifolds are removed	Taken off over hold-down studs after water is drawn from engine.
Type of gaskets	Johns Manville service packing.
Carburetors (see figs. 14, 18, and 19):	
Number	Two.
Name	Claudel-Hobson.
Type	Double inverted.
Manufacturer	Claudel Carburetor Co., Long Island City, N. Y.
Materials—	
Body	Aluminum alloy.
Nozzle	Brass.
Jets	Brass.
Type of strainer	Wire mesh.
Method of removing strainer	Held by brass cap.

MAIN JET SYSTEM.

Gasoline enters the carburetor at the bottom of the float chamber. It flows through the strainer and is admitted to the float chamber by the needle valve, which is operated by a conventional float mechanism. The fuel flows from the bottom of the float chamber to the main jet where it passes up into the emulsion well which contains a diffuser tube and an idling tube. The flow is then up to a horizontally drilled passage in the carburetor body communicating with the inverted, venturi-shaped discharge nozzle which is placed within the venturi-shaped choke. When the throttle is first opened a temporarily richer mixture is supplied by using the gasoline which has accumulated in the air well. This lowers the fuel level in the air well and uncovers a series of small holes in the diffuser tube. As the top of the air well is in direct communication with an air bleed from outside the carburetor, air is taken through the holes in the diffuser tube mixing with the gasoline in the emulsion well. This results in compensating for the tendency of the mixture to become richer as the throttle is opened. Adjustments of gasoline flow are made by changing the sizes of main jets and chokes and also by changing the location and sizes of the holes in the diffuser tube. The main jets can be reached for adjustment by removing a brass cap in the bottom of the air well.

IDLING SYSTEM.

The idling tube is supplied with fuel from the bottom of the emulsion well. Near the top of the tube are four small holes which are in direct communication with the air bleed and permit an emulsion of air and gasoline to be supplied to the idling nozzle through a drilled passage which is above the horizontally drilled passage to the main nozzle. The idling nozzle is placed downward through the inner venturi and passes through a slot in the barrel throttle. The idling adjustment is by means of a rod which can be screwed into this slot. The mixture is enriched by restricting the air flow. The mixture proportions for idling can also be changed by adjusting the size and number of the air bleed holes in the idling tube or by changing the size of the idling metering orifice.

AIR SYSTEM.

Air is admitted through an air scoop which is cut at 45° to the air stream from the propeller. The air passes downward through the venturi-shaped chokes. These are easily removable when the carburetor is taken apart at the flange above the float chamber. From the choke the air passes directly through the barrel throttle.

MIXTURE CONTROL.

The altitude control is based on the air bleed principle. The top of the float chamber is always in communication, by two large holes, to the air scoop. A cored passage across the top of the float chamber communicates, by drilled holes, to the horizontally drilled passages leading to the main nozzles.

The mixture control operates by admitting air to the horizontal nozzle passages, neutralizing, to a varying degree, the depression in the main gas passage and thereby reducing the flow of gasoline. The amount of air admitted to the nozzle passage is controlled by a valve consisting of a rod of varying cross section placed in an orifice between the cored passage and the outside of the carburetor.

Ignition (see fig. 15):	
Name of system	Berkshire.
Type	Magneto.
Manufacturer	Berkshire Magneto Co., Pittsfield, Mass.
Model	D6–2F–ES.
Number of magnetos	Two.
Number of cylinders and plugs per cylinder fired by each magneto.	One plug each in 12 cylinders.
Type of magnetos	Inductor.
Rotation	Both left hand.
Are magnetos interchangeable	Yes.
Distributors—	
Number	One per magneto.
Location	Front end.
Type of brush	Brass—air gap.
Magneto coupling	Rubber blocks.
Spark advance and retard mechanism.	Controlled from pilot's seat by rotating breaker mechanism.

Ignition—Continued.

Starting feature of magneto (battery excitation provided to insure sparking at low rotational speeds).	In the fully retarded position the battery is put in, and the magneto put out, of the circuit by means of an auxiliary contact.
Spark plugs—	
Name	A. C.
Manufacturer	Champion Ignition Co., Flint, Mich.

Auxiliaries (see fig. 16):

Gasoline pump: Gasoline is fed by a gear-driven, two-cylinder opposed plunger pump which is attached to the gear case. This pump has oil pressure from the main lubricating system maintained in its crank case to prevent gasoline leakage by the pistons. This pump is very similar to the one used on the Maybach engine.

Tachometer drives—	
Number	One.
Location	Lower part of gear case.
Airplane mounting:	
Type of mounting required	Straight engine bearers.
Connections and controls—	
Carburetor controls—	
Number	Two.
Nature	Throttle and altitude control.
Location	Above engine.
Type	Thrust rods.
Tachometer connection—	
Number	One.
Location	Lower part of gear case.
Cooling system connections—	
Number—	
Inlet	Two.
Outlet	Two.
Location	Rear of engine.
Lubrication system connections—	
Number	One thermometer; one pressure gauge.
Location	On left side of engine at mounting flange.
Fuel system connections—	
Number	Two.
Location	At bottom of float chambers of carburetors.
Ignition system connections—	
Number	Two.
Location	Magnetos.

METHOD OF TEST.

The engine was connected to an electric cradle dynamometer and the following runs were made in accordance with the standard method which is completely described in Engineering Division Report, Serial No. 1507:

Two full power runs from 1,550 revolutions per minute to 2,250 revolutions per minute, by increments of 100 revolutions per minute.

One friction horsepower run through same speed range as for full power runs. (Compression pressure taken at 120 revolutions per minute.)

Two propeller load runs from 2,250 revolutions per minute to 1,550 revolutions per minute.

One hour fuel and oil consumption run at 2,250 revolutions per minute.

One mixture control run at 2,250 revolutions per minute, 2,050 revolutions per minute, and 1,750 revolutions per minute.

One water circulation run through the engine from 1,450 revolutions per minute to 2,250 revolutions per minute by increments of 200 revolutions per minute.

One water pump capacity run with free outlet.

Trials to determine starting torque with engine hot and cold.

The temperature of the oil supplied to the bearings was taken between the pressure pump and the main bearings at a flange connection on the left side of the upper half of the crank case at No. 4 web.

The oil consumption was obtained during the one-hour run. After warming up the engine and before starting this test, the sump was nearly filled with oil and the amount marked on the oil gauge. After the test enough oil was added to bring the gauge back to the same mark and the amount added was taken as the oil consumption for that period.

RESULTS OF TEST.

The test results which appear in this report were obtained from manufacturer's engine No. 4. It must be borne in mind that in laboratory tests it is possible to operate an engine under more favorable conditions than in actual service. The engine under consideration when installed in an airplane, and run by the average pilot, will not develop the power nor have the fuel economy which is recorded in the tables and curves in this report.

It will be noted that the air temperature averages 70° F. and, therefore, the power results are perhaps a little lower than would have been obtained at the standard air temperature of 60° F. The power results are not corrected for temperature as no reliable method is at present available.

The performance tables are on pages 10 to 13. The performance curves are figures 21 to 24.

Referring to the table of efficiency factors on page 10, the air standard efficiency is the theoretical thermal efficiency based on the compression ratio and computed from the following formula, where E is the efficiency and R the compression ratio:

$$E=1-\left(\frac{1}{R}\right)^{0.408}$$

The relative indicated efficiency is the ratio of the indicated thermal efficiency to the air standard efficiency. The relative brake efficiency is the ratio of the brake thermal efficiency to the air standard efficiency.

OBSERVATIONS ON TEST.

The performance of this engine during the test was good and little trouble of any kind was experienced in operation of the engine. There appeared to be a marked freedom from vibration, even for a 12-cylinder engine of this type, but under laboratory conditions it is impossible to obtain reliable observations in regard to vibration, as the engine is very rigidly mounted.

The altitude control was kept in the full rich position at all times. If it was moved toward the lean position, both power and speed dropped off rapidly. Before starting the second propeller load run, some trouble was experienced with oil fouling of the A. C. spark plugs on the outside of the two banks of cylinders. The A. C. spark plugs on the outside were then replaced by Mosler M-1 mica spark plugs and satisfactory operation was obtained during the remainder of this run. Before starting the one-hour fuel and oil consumption run, the Mosler spark plugs caused pre-ignition and were removed and replaced by A. C. spark plugs. Satisfactory operation was then obtained during this run. The paper gasket of the water jacket at the front end of the engine broke during the one hour run causing a slight leakage of water.

INSPECTION AFTER TEST.

At the completion of the standard engine tests, the Curtiss model C-12 engine was completely disassembled for inspection. The following is a report on the condition of the various parts:

BEARINGS.

All bearings showed slight babbitt loading. The white metal had flowed over the edge of No. 2 and 6 main bearings. No. 8 main bearing was unevenly worn. The dowel screws of No. 4 main bearing were broken. The lower half of No. 6 connecting rod bearing had a small piece of white metal broken away.

PISTONS.

All pistons had a fairly heavy deposit of carbon.

GEARS.

Most of the propeller gear teeth showed uneven wear. The crank shaft reduction gear had several unevenly worn teeth. The teeth on the magneto bevel driving gears were burred.

VALVES.

Both exhaust valves leaked in every cylinder when tested with gasoline. Two intake valves leaked in cylinders Nos. 2, 4, 8, 11, and 12 and one in each of the other cylinders.

WATER PUMP.

The impeller hub was cracked and loose on the shaft and the impeller had cut the aluminum housing.

IGNITION.

The insulation of the ignition wires was cut, on the outlet of the manifold, by the sharp edge of the hole.

ENGINE MOUNTING LUGS OR FLANGES.

The holes for the hold-down studs had been slightly enlarged apparently by vibration.

All other parts showed normal signs of wear incident to a test of this nature.

ANALYSIS OF ENGINE.

DESIGN.

The general design is good and the engine assembly presents a compact, clean-cut appearance. The outstanding feature is the en-bloc cylinder construction which permits cooling water in direct contact with the steel liner or cylinder sleeve, except around the combustion chamber. The method of securing good contact of the liner in the cylinder head is particularly good.

The weight, dry, per normal brake horsepower of 1.633 pounds is exceptionally low. Judged only by the operation during this test, the major parts appear to be sufficiently heavy. The most noticeable saving of weight is in the crankshaft, which has very large bores in the crankpins and the main journals.

The bronze bearing bushings lined with white metal did not stand up as well as the aluminum bearing bushings lined with white metal, which are used in the Curtiss six-cylinder, model C-6 aviation engine. This may be due to the much higher speed and heavier loading of the C-12 rod-bearing assemblies.

The four valves are so located in the cylinder head that they can not be removed without first removing the valve guides. This makes valve grinding very difficult.

Oil from around No. 1 main bearing is taken to the cam-shaft bearings. An oil hole in the rear cam-shaft bearing support registers with a hole in the cylinder head. As there is no locating dowel pin, this support can be reversed, in which case the cam-shaft bearings will get no oil. This should be corrected by the addition of a dowel pin in the bearing support.

All the thrust on the cam shaft due to the use of bevel driving gears is taken by No. 1 bearing support. This is held by two small studs which do not appear strong enough to carry the load.

ADAPTABILITY TO PRODUCTION.

The engine presents no features which could not be easily handled in quantity production.

PERFORMANCE.

The performance of the engine on the dynamometer stand was good, with the exception of the oil consumption. The oil consumption at normal horsepower of 0.0832 pound per brake horsepower hour is extremely poor and precludes the use of a sump reservoir with this engine unless provision is made to replenish the supply in the sump during flight. For a pursuit ship which is to fly one-half hour at sea level and 2½ hours at 15,000 feet, 128.7 pounds of oil would be required, whereas the total capacity of the sump is only 36.7 pounds. The high oil consumption probably accounts for the fouling of the spark plugs, on the outside, during the propeller load run. Oil leakage past the very narrow main bearings between cylinders 1 and 2, 3 and 4, and 5 and 6 probably accounts in a large measure for this high consumption.

The full power curve peaks at 2,300 revolutions per minutes of the engine, at which speed the engine develops 425 brake horsepower. The brake mean effective pressure at normal speed of 131.3 pounds per square inch is excellent and is maintained fairly constant, thus indicating a high volumetric efficiency throughout the speed range. The maximum brake mean effective pressure, 137 pounds per square inch, is obtained at 1,750 revolutions per minute of the engine.

The specific fuel consumption at full throttle and normal speed of 0.503 pound per (actual) brake horsepower hour is good. The specific fuel consumption on propeller load increases rapidly as the throttle is closed. Since an engine in service operates most frequently at partial throttle, the average specific fuel consumption would be very much higher than it is at normal speed. A characteristic of the usual type Claudel-Hobson carburetor is to give practically as low specific fuel consumption on propeller load as at full power operation. The Claudel-Hobson inverted carburetor used on this engine departs from the usual construction in the use of a double venturi jet assembly. This double venturi is probably responsible for the rapid increase of specific fuel consumption on propeller load operation at the lower speeds.

The output of 0.373 brake horsepower per cubic inch of piston displacement at the normal speed is unusually

high, due to the high speed and brake mean effective pressure at which the engine operates.

ADAPTABILITY TO AIRPLANE.

This engine provides for straightforward mounting, requiring only two engine bed timbers. It is possible to slide the engine in and out on the bed timbers. The head resistance is not great.

ACCESSIBILITY.

The accessibility of all parts and accessories for adjustment and inspection is good. The carburetors can be reached for adjustment from above the engine. The magnetos can be reached through openings at the sides of the engine cowling. The outside spark plugs are easily reached for replacements. The inside spark plugs are not so conveniently located but are easily removed, as there is no interference with the carburetors. The water pump, tachometer, gasoline pump, and adjustable oil pressure relief valve can be easily reached for adjustments through openings properly located in the engine cowling.

MAINTENANCE.

The construction of the engines is such that overhauling can not be done without a considerable expenditure of time as compared with other engines. For instance, the valves can not be ground without removal of the valve guides which is an operation requiring special tools and more than average care. The clearance provided around many of the studs is insufficient to permit turning the nuts with socket wrenches. Many of the aluminum flanges on the engine are so thin as to be subject to breakage in handling or in drawing up on the bolts.

CARBURETORS.

The carburetors are unsatisfactory due to their high fuel consumption on propeller load and to the fact that they have several external air vents. These external vents entail some fire risk and preclude the use of a supercharger. It has been found that the type of mixture control used is unsatisfactory. Provision should be made so that in case of flooding of the carburetors, gasoline does not drain into the engine.

SUMMARY.

The test shows the need of improvement in the following details of the engine:

Valve design: To allow of removing valves without pulling guides.

Water pump: To strengthen hub of impeller.

Ignition wiring manifold: To prevent cutting of high-tension wire insulation.

Gear end cam-shaft bearings: To preclude possibility of assembling incorrectly, so as to cut off oil supply to cam shaft, and to provide more positive holding against end thrust of cam-shaft gears.

Bearings and lubrication system: To reduce oil consumption to a reasonable quantity.

Carburetors: To give better fuel economy on propeller load, to incorporate a more practical type of mixture control, to eliminate all external air vents, and to prevent filling up cylinders in case of flooding.

Bolt bosses and flanges.—To be more rugged and to allow clearance for use of socket wrench.

It is also believed that the lubrication of the reduction gears should be by a positive jet under pressure.

Since the Engineering Division is not interested in a geared engine of this size which can not be adapted to a cannon mounting, further tests on this engine are not contemplated. A direct drive model is being developed at the present time.

WEIGHTS OF CURTISS MODEL C-12 ENGINE AND PARTS.

		Weight (pounds).	Per cent of total.
Crank-case group, complete with bearings, studs, nuts, and breathers, including:			
1 upper half......pounds..	92.0		
1 lower half......do....	35.3		
Total......		127.3	18.24
Crank-shaft group, complete, with crank-shaft gear, reduction driving gear, oil tubes, etc......		61.3	8.78
Propeller shaft assembly, complete with ball bearing, reduction gear, and propeller hub rear flange.		40.0	5.73
Propeller hub assembly, front flange and bolts only......		15.0	2.15
Connecting-rod group, including 6 connecting-rod assemblies averaging 6.05 pounds each......		36.3	5.20
Piston group, including 12 piston assemblies complete with rings and pin, averaging 2.17 pounds each......		26.0	3.73
Cylinder group, including 2 cylinder blocks, of 6 cylinders each, complete with valves, valve springs, valve guides, and breathers......		203.5	29.16
Driving-gear group, including:			
2 cam-shaft drive shafts and housings......pounds..	9.0		
Gear case with magneto brackets......do....	12.2		
Upper vertical drive shaft and gears......do....	3.3		
Lower vertical drive shaft and gears......do....	1.0		
Oil pump drive......do....	1.0		
2 magneto drive couplings and tachometer drive......do....	3.2		
Total......		29.7	4.26
Cam-shaft group, including:			
4 cam-shafts complete with gears and bearings......pounds..	28.3		
2 cam-shaft housings, complete....do....	15.5		
24 cam followers......do....	6.8		
Total......		50.6	7.25
Lubrication group, including:			
1 oil pump assembly......pounds..	6.0		
Oil manifold and piping......do....	2.6		
Total......		8.6	1.23
Cooling system, including:			
Water pump assembly......pounds..	3.9		
Water manifolds......do....	7.5		
Total......		11.4	1.63
Carburetor and intake group, including:			
2 double carburetors......pounds..	18.8		
4 intake manifolds......do....	16.2		
Total......		35.0	5.01
Ignition group, including:			
2 magneto assemblies......pounds..	33.0		
Ignition wires and headers with distributor covers......do....	10.0		
24 spark plugs......do....	4.0		
Total......		47.0	6.73
Miscellaneous, cotter pins, wire, nuts, etc......		6.3	.90
Total weight, without auxiliaries......		698.0	100.00
Auxiliaries:			
1 gasoline pump......pounds..	3.6		
Storage battery for starting......do....	10.5		
Total......		14.1	......
Total weight of engine, with auxiliaries......		712.1	......
Weight of water in engine......		37.0	......

TABLE OF DIMENSIONS.

General:

- Bore .... 4.500 in.
- Stroke .... 6.000 in.
- Compression ratio .... 5.5:1.
- Gear ratio (propeller speed to engine speed) .... 3:5.
- Rotation of propeller (facing propeller). Counter-clockwise.
- Total piston displacement .... 1,145.0 cu. in.
- Approximate head resistance area .... 4.597 sq. ft.
- Firing order .... 1-6-7-10-3-2-11-8-5-4-9-12.
- Method of numbering cylinders .... From magneto end; even numbers on right, odd numbers on left.

Crank case:

- Distance between centers of cylinders No.—
  - 1–2 .... 5.187 in.
  - 2–3 .... 6.000 in.
  - 3–4 .... 5.187 in.
  - 4–5 .... 6.000 in.
  - 5–6 .... 5.187 in.
- Diameter main bearing studs .... Inside rows 7/16 in.
  - Do .... Outside rows 3/8 in.
- Capacity of oil sump .... 5 U. S. gallons.
- Main crank shaft bearings—

No.	Diameter.	Length.	Diametral clearance.	End clearance.	Projected area.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Sq. in.*
1	3.002	1.950	0.002	0.035	5.856
2, 4, 6	3.002	1.231	.002	.065	3.695
3, 5	3.002	2.000	.002	.125	6.006
7	3.002	2.877	.002	....	8.640
8	3.002	1.629	.002	....	4.892

- Engine hold-down bolts—
  - Number .... Ten.
  - Diameter .... 3/8 in.

Crank shaft:

No.	Outside diameter.	Length.	Diameter bore.
	Inches.	*Inches.*	*Inches.*
Main journals—			
1	3.000	1.985	2.500
2, 4, 6	3.000	1.316	2.500
3, 5	3.000	2.125	2.500
7	3.000	3.440	2.500
8	3.000	2.656	2.500
Crank pins—			
1, 2, 3, 4, 5, 6	2.500	2.142	1.875

- Crank cheeks—
  - Width .... 3.500 in.
  - Thickness .... 0.847 in.

Reduction gear:

- Ratio propeller speed to crank-shaft speed .. 3:5.
- Circular pitch of gears .... 0.6185 in.
- Tooth form .... Herringbone.
- Backlash .... 0.003 in.
- Crank-shaft gear—
  - Number of teeth .... 30.
  - Face width .... 2.191 in.
- Propeller-shaft gear—
  - Number of teeth .... 50.
  - Face width .... 2.191 in.
- Journal—
  - Outside diameter .... 2.500 in.
- Propeller-shaft bearings—

	Diameter.	Length.	Diametral clearance.
	Inches.	*Inches.*	*Inches.*
Front	2.502	4.007	0.002
Rear	None.	....	....

Reduction gear—Continued.

- Thrust bearing—
  - Number of balls .... 8.
  - Diameter of balls .... 0.875 in.
  - Diameter of ball circle .... 4.000 in.
  - Manufacturer .... Hess-Bright.
  - Manufacturer's No .... 8313.

Propeller hub:

- Diameter hub body .... 2.188 in.
- Length between flanges—
  - Minimum .... 5.750 in.
  - Maximum .... 7.375 in.
- Diameter bolt circle .... 8.125 in.
- Bolts—
  - Number .... 8.
  - Minimum outside diameter .... 0.625 in.
  - Maximum outside diameter .... 0.765 in.
  - Bore .... 0.375 in.
  - Thread .... 18 threads per inch.

Connecting rods:

- Length of main rod, center to center .... 10.000 in.
  - Number of bolts to hold cap .... Four.
- Minimum diameter of shank (bolts) .... 0.311 in.
- Thread (bolts) .... 3/8-inch, 24 threads per inch.
- Length of articulated rod, center to center .. 7.750 in.
  - Number of bolts to hold hinge pin .... One.
- Minimum diameter of shank (bolts) .... 0.311 in.
- Thread (bolts) .... 3/8-inch, 24 threads per inch.
- Rod-stroke ratio .... 1.667:1.
- Piston-pin bushing—
  - Length .... 1.630 in.
  - Diameter, inside .... 1.126 in.
  - Projected area .... 1.836 sq. in.
  - End play of rod .... 0.124 in.
  - Clearance to pin .... 0.001 in.
- Big end bearing, main rod—
  - Length .... 2.125 in.
  - Diameter .... 2.502 in.
  - Clearance on crank pin—
    - Diametral .... 0.002 in.
    - End .... 0.017 in.
  - Projected area on crank pin .... 5.315 sq. in.
- Hinge-pin bushing, articulated rod—
  - Length (total) .... 1.330 in.
  - Diameter .... 1.127 in.
- Diametral clearance on hinge pin .... 0.002 in.

Pistons:

- Area of head .... 15.91 sq. in.
- Distance from center of pin to top of piston. 1.625 in.
- Length over all .... 3.750 in.
- Clearance in cylinder—
  - Top .... 0.021 in.
  - Bottom .... 0.018 in.
- Rings—
  - Number per piston .... 3.
  - Tension .... 5 lb.
  - Width—
    - Two upper rings .... 0.125 in.
    - One lower ring .... 0.094 in.
- Width of gap (ring in cylinder) .... 0.010 in.
- Pin—
  - Length .... 3.928 in.
  - Diameter .... 1.125 in.
  - Diameter bore, ends .... 0.925 in.
  - Diameter bore, center .... 0.797 in.
  - Total length of bearing in piston .... 2.174 in.

Cylinders:

- Bore .... 4.500 in.
- Stroke .... 6.000 in.
- Stroke-bore ratio .... 1.333:1.
- Piston displacement per cylinder .... 95.40 cu. in.
- Total piston displacement of engine .... 1,145 cu. in.
- Compression volume of cylinder .... 21.19 cu. in.
- Total volume of cylinder .... 116.59 cu. in.
- Compression ratio .... 5.5:1.
- Per cent compression .... 18.18 per cent.

Cylinders—Continued.

Port openings—

	Intake.	Exhaust.
Number per cylinder	2	2.
Shape	Elipse	Elipse.
Height	1.500 in	1.500 in.
Width	1.750 in	1.750 in.
Number of studs	20 studs to 12 ports	

Water connections—

	Number.	Inside diameter.
		Inch.
Inlet	6	0.625
Outlet	6	0.625

Hold-down studs per cylinder—

Number.	Diameter.	Threads per inch.
	Inch.	
4	$\frac{5}{16}$	24

Cam shafts (four):

Outside diameter .... 1.003 in.

Journals—

Number.	Diameter.	Length.
	In.	*In.*
6	1.061	1.500

Bearings—

Number.	Diameter.	Length.
	In.	*In.*
6	1.064	1.500

Cams—

Body diameter.	Width.	Lift.
	In.	*In.*
Intake, 1.124 inches	0.570	0.417
Exhaust, 1.124 inches	0.570	0.417

Valves:

Inlet and exhaust valves—

- Number of each per cylinder .... Two.
- Outside diameter .... 1.800 in.
- Inside diameter of seat .... 1.628 in.
- Lift .... 0.402 in.
- Angle of seat .... 45°.
- Angle of stem with cylinder axis .... Parallel.
- Total area of opening (each valve) .... 1.646 sq. in.
- Stem diameter .... 0.343 in.
- Tappet clearance .... 0.015 in.

Valve springs—

- Number per valve .... Two.
- Tension inlet (both springs)—
  - Valve open .... 42.0 lb.
  - Valve closed .... 27.0 lb.

Valves—Continued.

Valve springs—Continued.

- Tension exhaust (both springs)—
  - Valve open .... 42.0 lb.
  - Valve closed .... 27.0 lb.
- Internal spring tension—
  - Valve closed .... 20.5 lb.
  - Valve open .... 29.0 lb.

Valve timing—

	Actual.	Designed.
Inlet:		
Opens	1° late	
Closes	46° late	42° late.
Exhaust:		
Opens	58° early	58° early.
Closes	6° late	

Oil pump (gear type):

	Pressure.	Scavenging.
Number	One	Two (using a common gear).
Material, casing	Aluminum alloy	Alluminum alloy.
Material, gears	1 steel, 1 bronze	1 steel, 2 bronze.
Speed	Crank-shaft	Crank-shaft.
Number of gears	Two	Three.
Pitch diameter, gears	1.250 in	1.250 in.
Number of teeth	10	10.
Face width	0.743 in	0.743 in.

Water pump:

- Material—
  - Housing .... Aluminum alloy.
  - Impeller .... Aluminum alloy.
- Type .... Centrifugal.
- Speed .... $1\frac{1}{2}$ crank-shaft speed.
- Diameter impeller .... 4.000 in.
- Number of vanes .... 8 (shrouded).
- Number of inlets—inside diameter .... One ($1\frac{1}{2}$ in.).
- Number of outlets—inside diameter .... Two ($\frac{11}{16}$ in.).
- Diameter shaft .... 0.567 in.
- Water connections to engine—
  - Number of inlets—inside diameter .... One ($1\frac{1}{2}$ in.).
  - Number of outlets—inside diameter .... Two ($1\frac{1}{8}$ in.).

Carburetors:

- Number .... Two double inverted.
- Material, body .... Aluminum alloy.
- Diameter at the flange, inside .... 2.000 in.
- Chokes diameter .... 1.458 in.
- Metering jets, material .... Brass.
- Diameter main jet .... 42 drill size.
- Diameter idling jet .... 71 drill size.

Ignition:

- Maximum spark advance .... 30° before top center.
- Maximum retard .... 6° after top center.
- Number of magnetos .... Two.
- Speed, pole pieces .... $1\frac{1}{2}$ crank-shaft speed.
- Speed, distributor .... $\frac{1}{2}$ crank-shaft speed.
- Width of breaker gap .... 0.020 in.

Spark plugs:

- Size of thread .... 18 mm. diameter—1.5 mm. pitch (S. A. E. metric).
- Gap .... 0.017 in.

Auxiliaries:

- Gasoline pump—
  - Speed .... $\frac{1}{2}$ crank-shaft speed.
  - Bore .... 1.015 in.
  - Stroke .... 0.563 in.
  - Inside diameter inlet .... 0.375 in.
  - Inside diameter outlet .... 0.375 in.
- Tachometer drive connection—
  - Speed .... $1\frac{1}{2}$ crank-shaft speed.
  - Outside diameter threads .... 0.868 in.
  - Thread .... 18 threads per inch.

EFFICIENCY FACTORS FOR CURTISS MODEL C-12 AVIATION ENGINE AT NORMAL ENGINE SPEED OF 2,250 REVOLUTIONS PER MINUTE.

Cubic inches of piston displacement per b. hp....	2.680 cu. in.
B. hp. per cubic inch of piston displacement...	0.373 b. hp.
B. hp. per cubic foot of piston displacement....	645.0 b. hp.
B. hp. per square foot of piston area...........	322.5 b. hp.
Piston speed in feet per minute................	2,250 ft. per min.
Indicated mean effective pressure..............	151.8 lb. per sq. in.
Friction mean effective pressure...............	20.5 lb. per sq. in.
Brake thermal efficiency [1].....................	24.05 per cent.
Indicated thermal efficiency [1]..................	27.80 per cent.
Air standard efficiency..........................	50.12 per cent.
Relative indicated efficiency...................	55.50 per cent.
Relative brake efficiency.......................	48.05 per cent.
Mechanical efficiency............................	86.40 per cent.
Weight per cubic inch of piston displacement..	0.6095 lb.

[1] Based on a fuel heat content of 21,000 B. T. U. per pound.

POWER PLANT WEIGHT BY CLASS OF SERVICE (POUNDS).

Weight factors.	Pursuit.[1]	Two-place.[2]	Training.[3]
Engine weight, dry......................	702.0	702.0	702.0
Power plant constant weight...........	104.6	104.6	104.6
Cooling system..........................	277.8	277.8	277.8
Tankage..................................	191.0	304.6	226.3
Fuel......................................	418.3	711.7	451.8
Oil..	128.7	182.0	110.9
Total..............................	1,822.4	2,282.7	1,873.4
Per horsepower.........................	4.264	5.341	4.383

[1] ½ hour at sea level, 2½ hours at 15,000 feet.
[2] ½ hour at sea level, 4 hours at 10,000 feet.
[3] 2½ hours at sea level.

Altitude.	Horsepower (see curve, fig. 23).	Fuel consumption lb. per hr.
Sea level..	427.4	214.6
10,000 feet..	278.6	151.1
15,000 feet..	214.4	124.4

FULL POWER RUNS.

FIRST RUN.

Eng. r. p. m.	Actual.		Corrected.			Water.		Oil.			Carb. air, temp. °F.	Man. vac., in. Hg.	Float chamber vac., in. water.	Fuel cons.		
	Brake load, lb.	B. hp.	Crankshaft torque, lb. ft.	Hp.	B. m. e. p., lb. per sq. in.	Temp. °F.		Temp. °F.		Press., lb. per sq. in.				Sec. for 5 lb.	Lb. per hp. hr.	Lb. per hr.
						In.	Out.	Sump.	Bearings.							
1,554.....	952	295.9	1,030	305.0	135.6	144	166	79	138	85	70	1.0	2.0	111.6	0.545	161.2
1,661.....	956	317.4	1,034	327.2	136.2	136	156	81	140	87	70	1.1	2.3	108.2	0.525	166.5
1,753.....	962	337.5	1,041	348.0	137.1	140	164	86	145	87	70	1.2	2.7	103.2	0.517	174.4
1,870.....	968	358.3	1,036	369.4	136.4	138	158	86	150	88	70	1.3	3.0	98.4	0.511	183.0
1,950.....	949	370.4	1,026	381.5	135.2	138	160	88	152	88	70	1.5	3.4	96.8	0.502	185.9
2,050.....	941	385.8	1,018	397.8	134.2	138	162	91	158	89	70	1.7	3.8	93.0	0.502	193.6
2,167.....	928	402.2	1,004	414.6	132.3	140	162	93	160	88	70	1.8	4.1	90.4	0.496	199.4
2,283.....	906	413.7	981	426.5	129.2	140	160	95	158	85	70	1.9	4.4	87.2	0.499	206.5

Barometer, 29.01 in. Hg.

SECOND RUN.

Eng. r. p. m.	Actual.		Corrected.			Water.		Oil.			Carb. air, temp. °F.	Man. vac., in. Hg.	Float chamber vac., in. water.	Fuel cons.		
	Brake load, lb.	B. hp.	Crankshaft torque, lb. ft.	Hp.	B. m. e. p., lb. per sq. in.	Temp. °F.		Temp. °F.		Press., lb. per sq. in.				Sec. for 5 lb.	Lb. per hp. hr.	Lb. per hr.
						In.	Out.	Sump.	Bearings.							
1,567......	939	294.3	1,018	303.7	134.2	138	160	77	130	85	70	0.9	1.9	112.0	0.545	160.7
1,667......	953	317.7	1,032	327.7	135.9	138	160	79	128	85	70	1.0	2.2	110.0	0.516	163.9
1,750......	949	332.3	1,028	342.8	135.5	140	162	81	132	85	70	1.2	2.5	104.2	0.520	172.7
1,850......	954	353.1	1,033	364.2	136.1	138	160	82	145	87	70	1.3	2.7	100.6	0.507	178.9
1,983......	952	377.6	1,031	389.5	135.8	138	158	84	150	88	70	1.5	3.0	96.0	0.497	187.6
2,050......	944	387.0	1,023	399.1	134.8	140	160	86	155	88	70	1.7	3.4	94.6	0.492	190.3
2,150......	922	396.5	998	409.0	131.5	140	160	90	160	87	72	1.8	3.7	91.0	0.499	197.8
2,250......	902	406.0	977	419.0	128.7	140	160	95	163	85	74	1.9	4.1	88.8	0.499	202.6

Barometer, 29.01 in. Hg.
NOTE.—The best setting for the altitude control was found to be in the full rich position.

PROPELLER LOAD RUNS.

FIRST RUN.

Eng. r. p. m.	Actual.		Corrected.		Water.		Oil.			Carb. air temp. °F.	Man. vac., in. Hg.	Float chamber vac., in. water.	Fuel cons.		
	Brake load, lb.	B. hp.	Crank-shaft torque, lb. ft.	Hp.	Temp. °F. In.	Temp. °F. Out.	Temp. °F. Sump.	Temp. °F. Bearings.	Press., lb. per sq. in.				Sec. for 5 lb.	Lb. per hp. hr.	Lb. per hr.
2,267	914	414.7	989	427.4	136	163	95	152	92	70	2.0	4.2	85.0	0.511	211.9
2,150	813	349.6	880	360.1	136	158	99	161	87	70	3.7	3.4	99.2	0.519	181.4
2,017	735	296.6	796	305.5	138	158	99	160	85	70	5.0	2.7	110.6	0.549	162.8
1,950	672	261.6	728	269.5	140	160	99	152	87	70	5.7	2.0	120.0	0.574	150.2
1,833	598	219.3	647	225.9	141	159	100	149	85	70	6.7	1.4	130.2	0.631	138.3
1,767	548	193.7	593	199.5	143	160	99	142	85	72	7.4	0.6	136.0	0.684	132.4
1,633	489	159.7	529	164.4	144	159	77	130	88	78	9.5	0.0	148.6	0.759	121.1
1,533	437	134.0	473	138.0	147	157	77	132	84	80	10.5	0.0	157.6	0.853	114.2

Barometer, 29.04 in. Hg.

SECOND RUN.

Eng. r. p. m.	Actual.		Corrected.		Water.		Oil.			Carb. air temp. °F.	Man. vac., in. Hg.	Float chamber vac., in. water.	Fuel cons.		
	Brake load, lb.	B. hp.	Crank-shaft torque, lb. ft.	Hp.	Temp. °F. In.	Temp. °F. Out.	Temp. °F. Sump.	Temp. °F. Bearings.	Press., lb. per sq. in.				Sec. for 5 lb.	Lb. per hp. hr.	Lb. per hr.
2,250	912	410.6	988	423.5	136	160	82	148	92	82	2.0	4.1	90.4	0.485	199.2
2,133	827	352.9	896	363.9	148	164	88	162	85	82	3.4	3.4	102.0	0.500	176.4
2,050	756	309.9	819	319.5	144	161	86	162	85	81	4.6	2.5	107.8	0.539	167.0
1,967	679	267.2	735	275.5	140	157	86	160	85	82	5.8	1.9	115.8	0.581	155.2
1,850	615	227.6	666	234.7	140	157	84	158	83	82	7.0	1.3	125.2	0.632	143.8
1,750	551	192.8	597	198.8	145	162	82	152	83	83	8.3	0.7	134.6	0.694	133.8
1,650	491	162.0	532	167.0	145	160	79	146	81	82	9.3	0.2	147.6	0.753	121.9
1,550	435	134.8	471	139.0	147	160	79	140	81	82	10.2	0.0	163.6	0.817	110.2

Barometer, 29.02 in. Hg.

ONE HOUR FUEL AND OIL CONSUMPTION RUN.

Engine r. p. m.	Actual.		Corrected.			Water.		Oil.			Carb. air temp., °F.	Man. vac., in. Hg.	Float vac., in. Hg.	Fuel cons.	
	Brake load, lb.	B. hp.	Crank-shaft, torque, lb. ft.	Hp.	B. m. e. p., lb. per sq. in.	Temp., °F. In.	Temp., °F. Out.	Temp., °F. Sump.	Temp., °F. Bearings.	Press., lb. per sq. in.				Scale reading, lb.	Lb. per hp. hr.
....	931	....	1,008	....	132.8	132	156	90	148	94	63	2.0	0.3	86.0	....
2,233	926	413.5	1,002	426.5	131.9	138	162	95	165	85	64	2.0	0.3	68.8	0.499
2,237	922	412.5	1,000	425.5	131.7	137	158	97	168	82	64	2.0	0.3	51.5	0.503
2,240	918	411.5	995	424.5	131.0	136	160	97	171	80	64	2.0	0.3	34.0	0.510
2,233	916	409.0	993	422.0	130.8	138	162	99	171	80	65	2.0	0.3	113.4	....
2,223	918	408.1	995	421.0	131.0	136	160	100	170	82	67	2.0	0.3	96.4	0.500
2,227	918	408.9	995	421.9	131.0	135	160	104	170	83	67	2.0	0.3	79.2	0.505
2,230	918	409.5	995	422.5	131.0	137	160	75	152	89	68	2.0	0.3	62.0	0.504
2,230	917	409.2	994	422.3	130.9	138	160	73	147	93	68	2.0	0.3	44.8	0.505
2,230	918	409.5	995	422.5	131.0	136	160	86	165	85	66	2.0	0.3	114.7	....
2,230	920	410.5	998	423.5	131.4	137	160	95	169	83	66	2.0	0.3	97.7	0.497
2,227	922	410.7	1,000	423.7	131.7	135	160	97	170	82	67	2.0	0.3	80.7	0.497
2,217	918	407.0	995	419.9	131.0	134	.159	97	170	82	66	2.0	0.3	63.5	0.507

AVERAGE RESULTS.

2,230	920	410.5	998	423.5	131.5	136	159	93	164	85	66	2.0	0.3	[1] 171.8	0.503

[1] For 50 minutes.

NOTE.—37 pounds of oil was used in 65 minutes, giving a specific oil consumption of 0.0832 lb. per hp. hr.
Readings were taken every five minutes. Average barometer, 29.00 in. Hg.
Data for all runs: Length of brake arm, 21 inches; kind of oil used, 75 per cent castor, 25 per cent Mobiloil B; specific gravity, gasoline, 0.710 at 60° F.

FRICTION HORSEPOWER AND COMPRESSION PRESSURE RUN.

Engine r. p. m.	Propeller r. p. m.	Corrected engine b. h. p. (from curve) (fig. 21).	Friction load, lb.	Friction horsepower.	Friction m. e. p., lb. per sq. in.	Per cent mechanical efficiency.	Cylinder No.	Comp. press., lb. per sq. in.[1]
1,550	930	303	103	31.9	14.23	90.5	1	104
1,650	990	322	110	36.3	15.21	89.9	2	108
1,750	1,050	344	116	40.6	16.04	89.5	3	102
1,850	1,110	364	122	45.2	16.89	89.0	4	107
1,950	1,170	383	127	49.6	17.58	88.5	5	107
2,050	1,230	399	131	53.8	18.14	88.1	6	122
2,150	1,290	412	139	59.8	19.22	87.4	7	106
2,250	1,350	422	148	66.6	20.46	86.4	8	108
							9	106
							10	108
							11	107
							12	110

[1] The compression pressure was taken at 120 r. p. m. (engine speed).

NOTE.—This friction horsepower run was made immediately after the second propeller load run. The water and oil temperatures were maintained the same as during that run.

Length of brake arm, 21 inches; oil used, 75 per cent castor, 25 per cent Mobiloil B; room temperature, 77° F.

MIXTURE CONTROL RUN.[1]

Positions of altitude cont.	R. p. m.	Actual.		Corrected.			Water.		Oil.			Carb. air, temp. °F.	Man. vac., in. Hg.	Float chamber, vac. in. water.	Fuel cons.	
		Brake load, lb.	B. hp.	Torque, lb. ft.	Hp.	B. m. e. p., lb. per sq. in.	Temp. °F. In.	Temp. °F. Out.	Temp. °F. Sump.	Temp. °F. Bearings.	Press., lb. per sq. in.				Sec. for 5 lb.	Lb. per hp. hr.
Full rich	2,250	912	410.6	989.0	423.7	130.3	137	159	99	125	103	66	2.0	4.1	85.8	0.511
Full rich	[1] 2,050	760	311.6	824.0	321.6	108.6	138	158	88	159	85	66	4.5	2.7	108.8	0.531
Full rich	[1] 1,767	657	232.2	712.0	239.6	93.8	142	160	84	150	83	66	6.6	1.4	123.6	0.628
Full lean	2,250	880	396.1	954.0	408.9	125.6	138	160	99	161	87	66	2.0	4.1	98.6	0.461
Full lean	[1] 2,050	744	305.1	806.5	314.9	106.3	140	161	90	158	85	66	4.6	2.8	118.0	0.500
Full lean	[1] 1,767	647	228.7	701.5	235.9	92.4	142	160	82	147	84	66	6.8	1.4	134.6	0.585

[1] Engine throttled as on propeller load operation.

Average barometer, 28.99 in. Hg.

Data for all runs: Kind of oil, 75 per cent castor, 25 per cent Mobiloil B; specific gravity gasoline, 0.710 at 60° F.; length of brake arm, 21 inches.

WATER CIRCULATION RUN THROUGH ENGINE.

Engine r. p. m.	Water temp. °F. tank.[1]	Flow through engine. Measured flow. Pounds.	Flow through engine. Measured flow. Seconds.	Flow through engine. Gallons per minute.
1,450	114	177.5	25.8	49.9
1,650	110	173.6	21.6	58.2
1,850	103	172.5	19.2	65.2
2,050	107	171.5	17.6	70.7
2,250	109	173.7	16.6	75.8

[1] Discharge into measuring tank.

NOTE.—One gallon of water at 108° F. weighs 8.28 lb.

STARTING TORQUE.

Engine cold. Throttle.	Starting torque—lb. ft. 1[2]	2[2]	3[2]	Average.	Engine warm. Throttle.	Starting torque—lb. ft. 1[2]	2[2]	3[2]	Average.
Open	250.2	225.8	224.0	233.3	Open	257.3	259.0	253.8	256.7
Closed	259.0	252.0	271.3	260.8	Closed	174.7	253.8	253.8	227.4

Trial number.

WATER PUMP CAPACITY RUN, FREE INTAKE AND DISCHARGE.

Speed r. p. m.		Drive torque,[3] lb. ft.	Drive horse-power.	Flow.	
Pump.	Engine (crank-shaft).			Sec. for 200 lb.	Gallons per minute.
2,325	1,550	1.5	0.665	19.6	73.5
2,625	1,750	1.9	0.950	17.6	82.0
2,925	1,950	2.3	1.282	15.8	91.3
3,225	2,150	2.7	1.659	14.2	101.5

[3] 12-inch arm.

NOTE.—Maximum pressure at normal engine speed of 2250 r. p. m. is 20 lb. per sq. in.

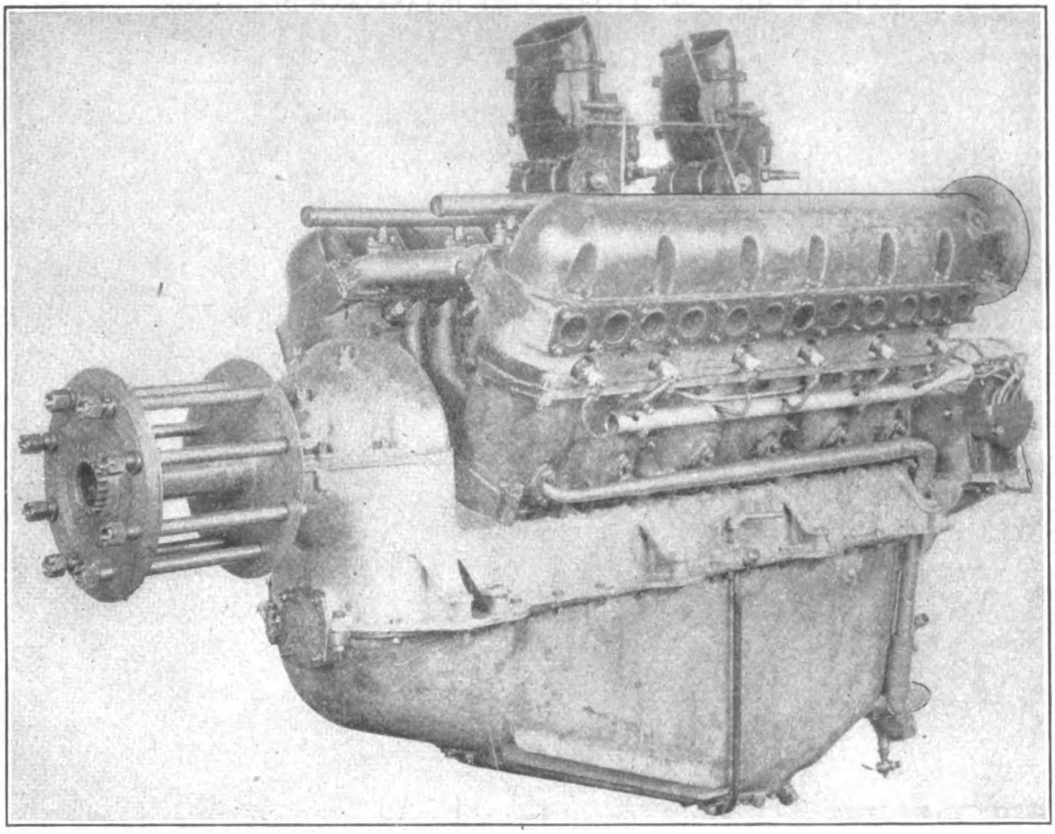

FIG. 1.—Three-quarter view (front and left side).

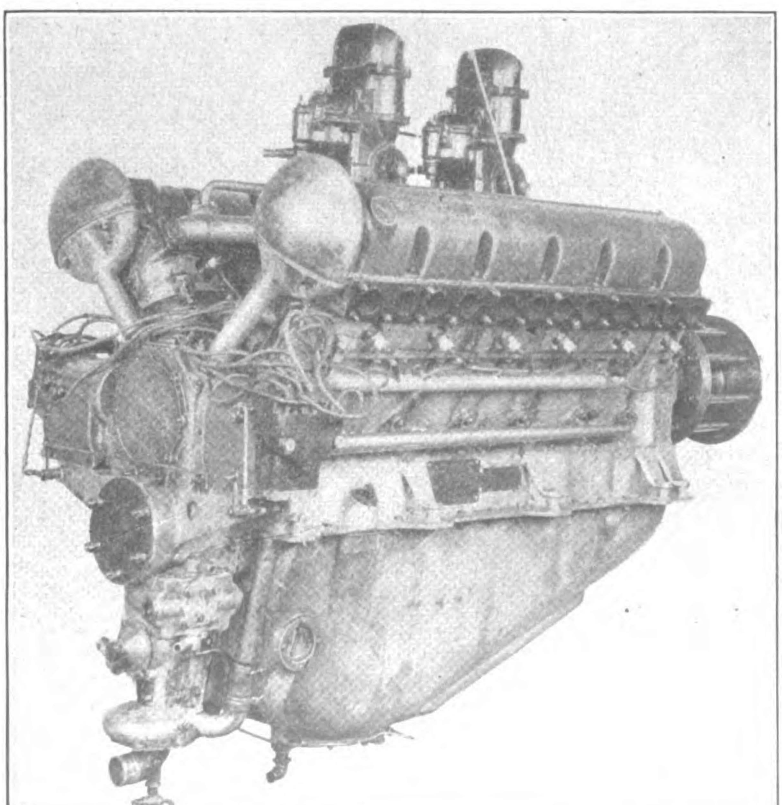

FIG. 2.—Three-quarter view (rear and right side).

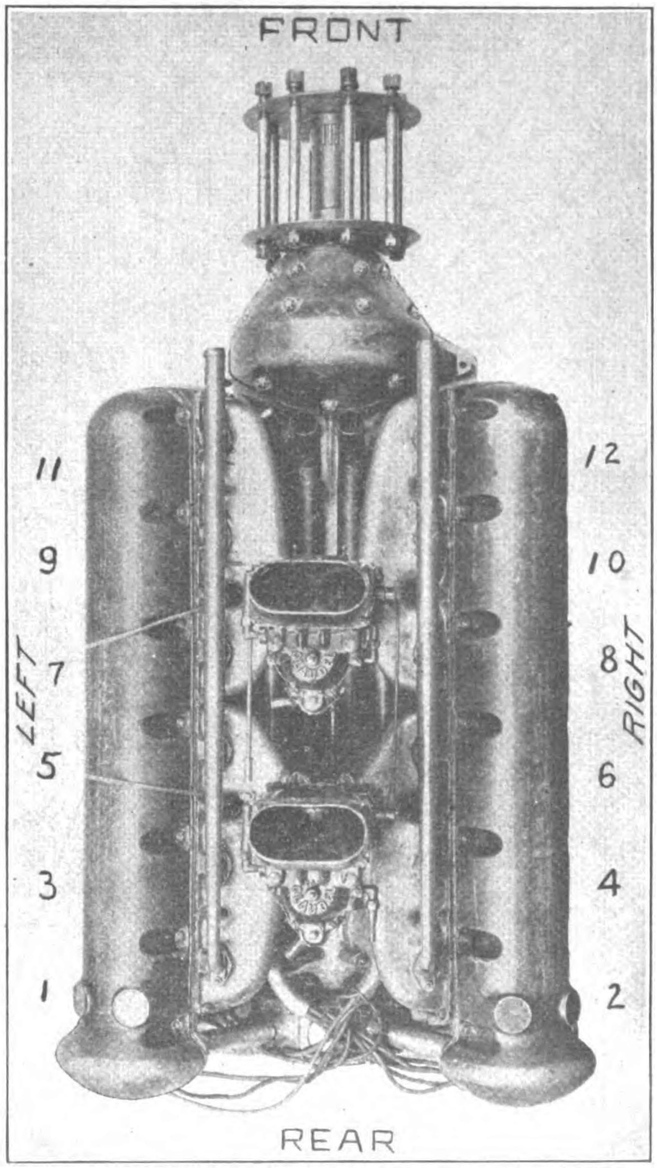

Fig. 3.—Plan view.

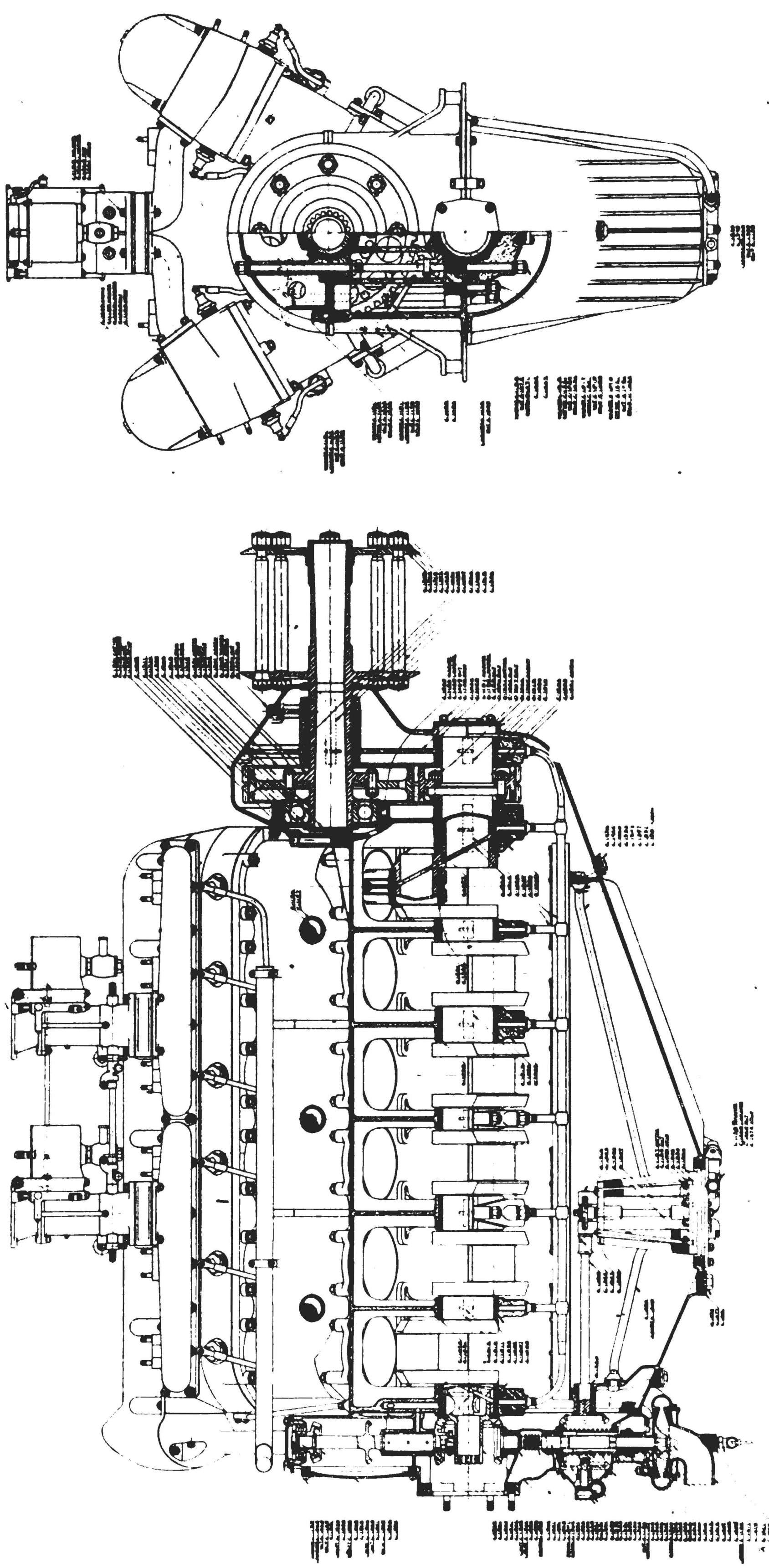

FIG. 4.—Longitudinal section and propeller end view

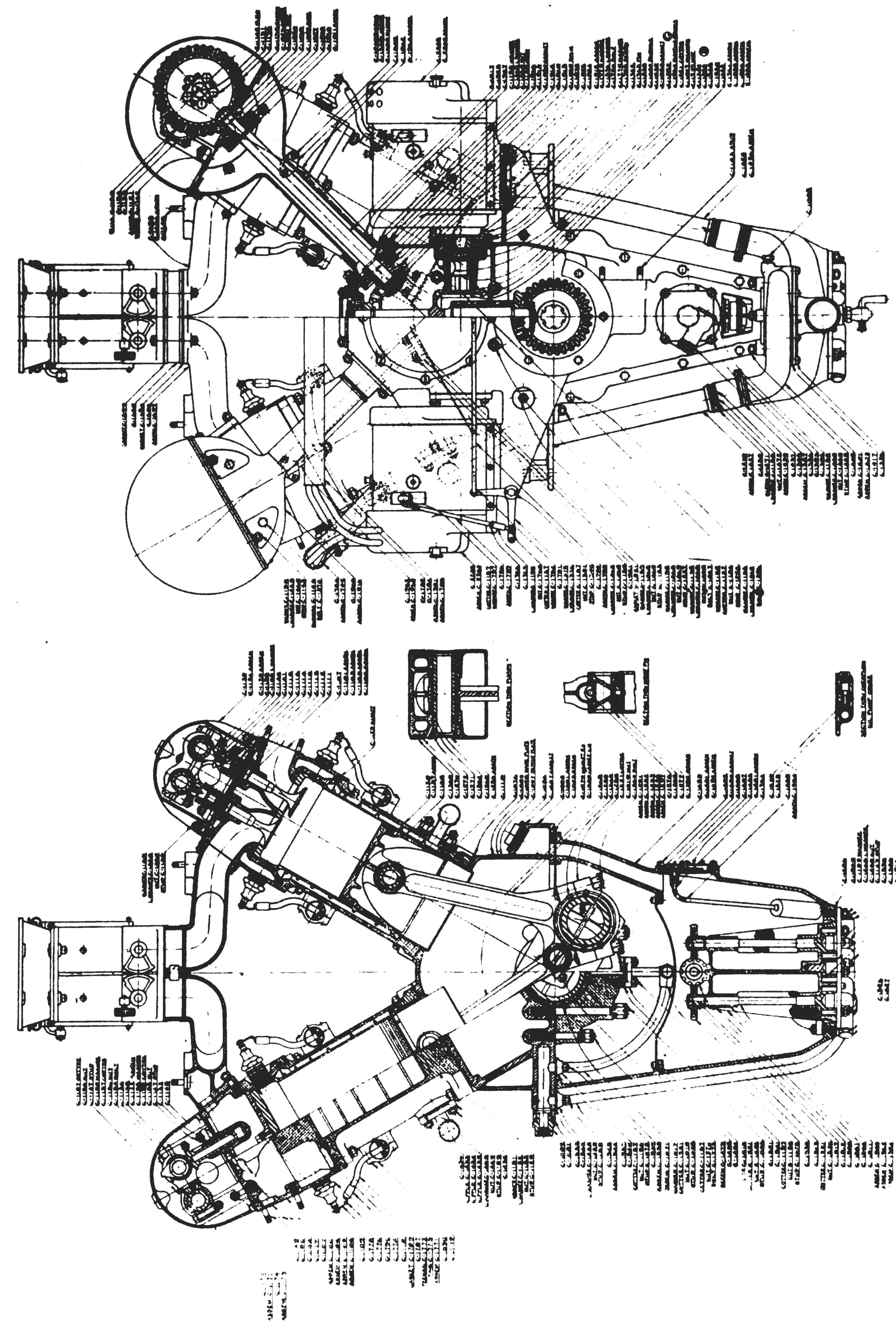

Fig. 5.—Transverse section and rear end view.

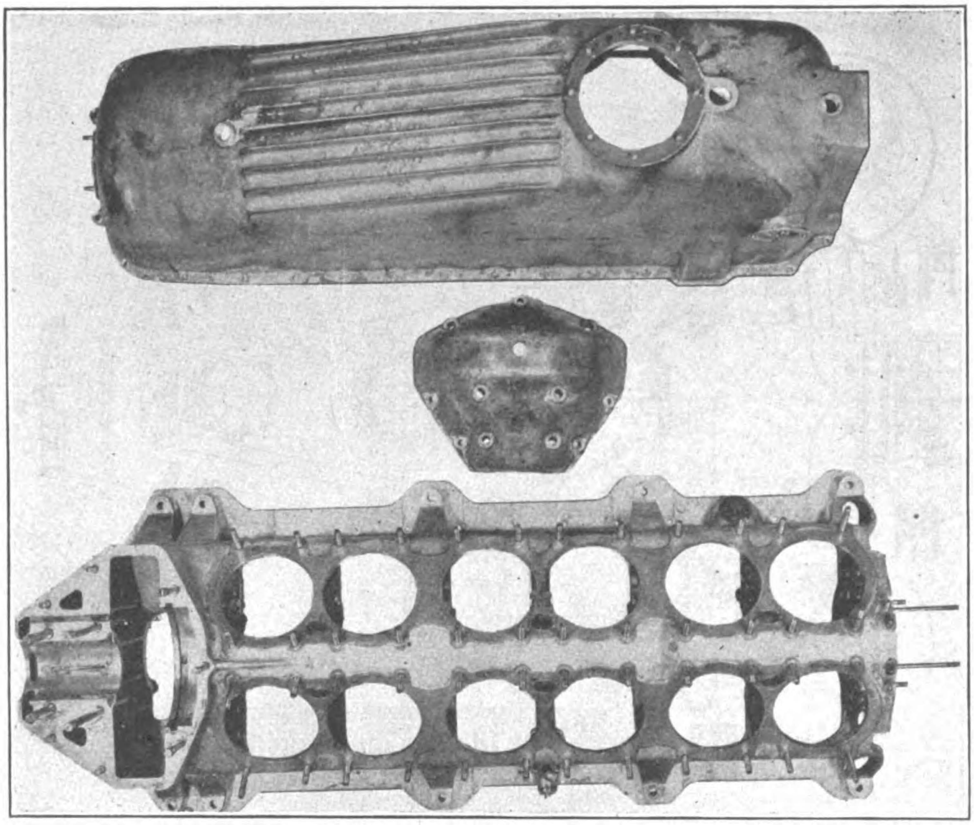

FIG. 6.—Crankcase, upper and lower halves, outside view.

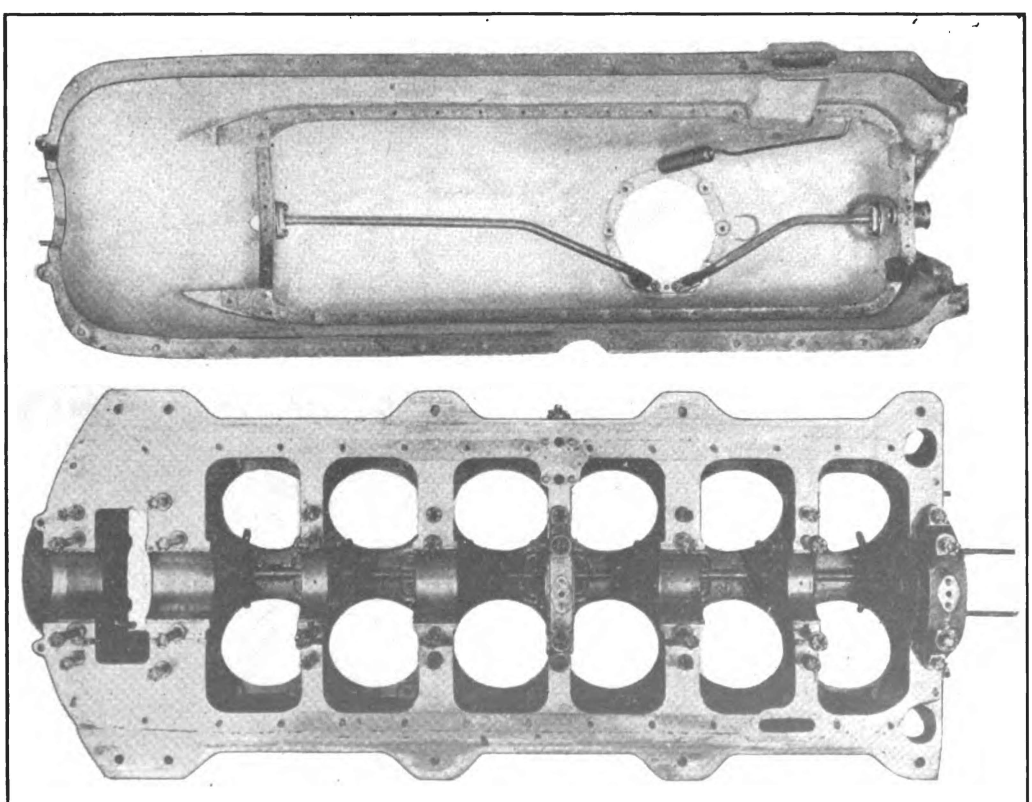

FIG. 7.—Crankcase ,upper and lower halves, inside view.

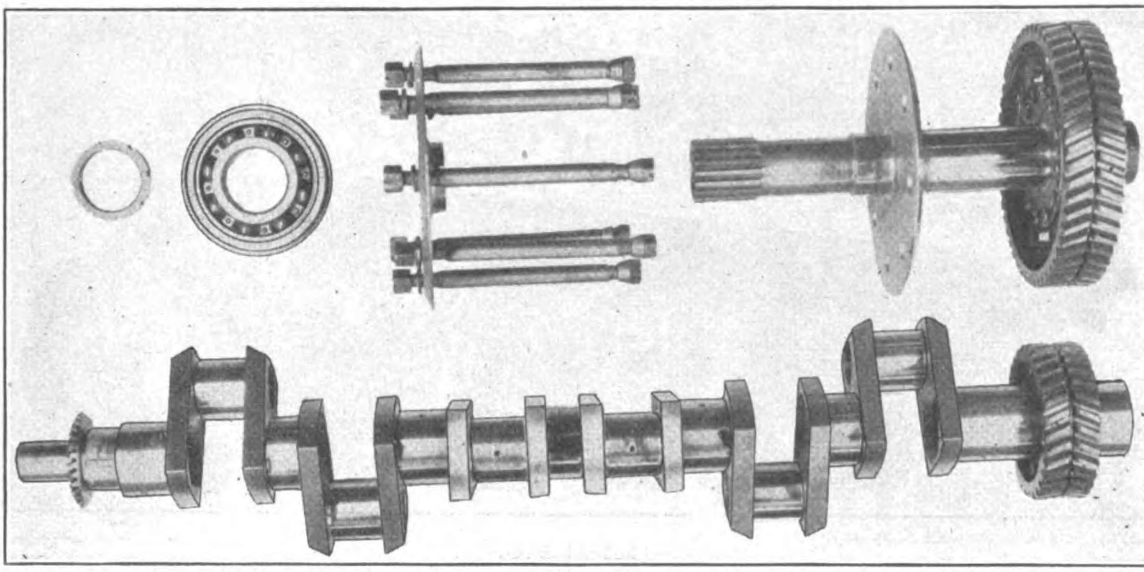

FIG. 8.—Crankshaft, reduction gear, propeller shaft, and propeller hub.

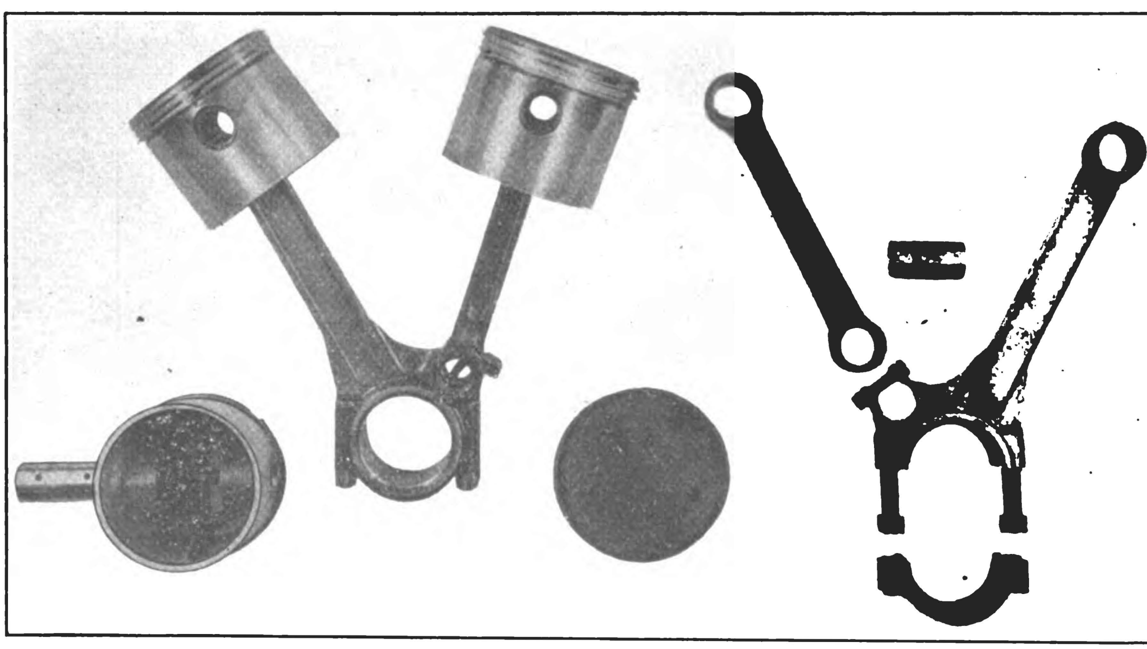

FIG. 9.—Pistons and connecting rods.

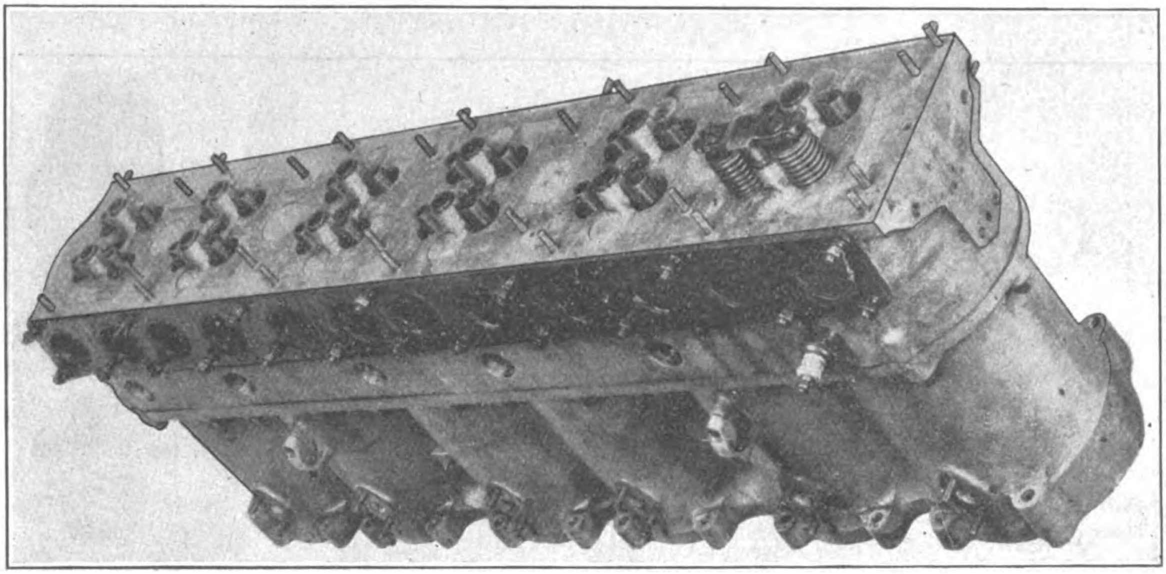

Fig. 10.—Cylinder block assembly.

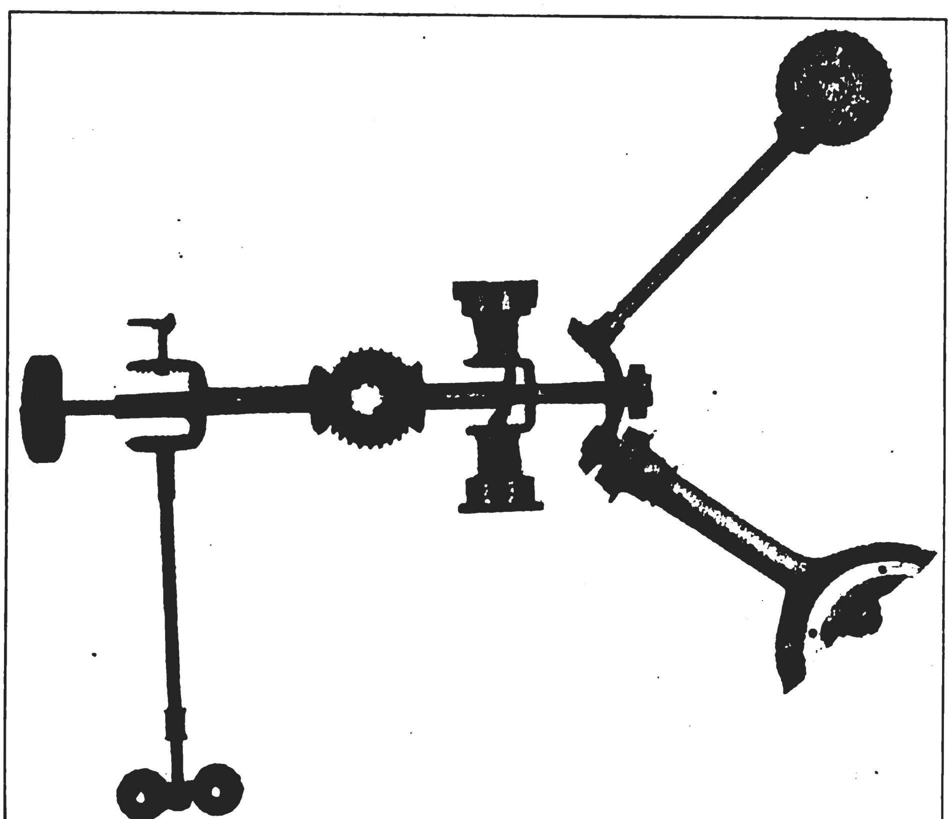

Fig. 11.—Drives laid out according to location of engine.

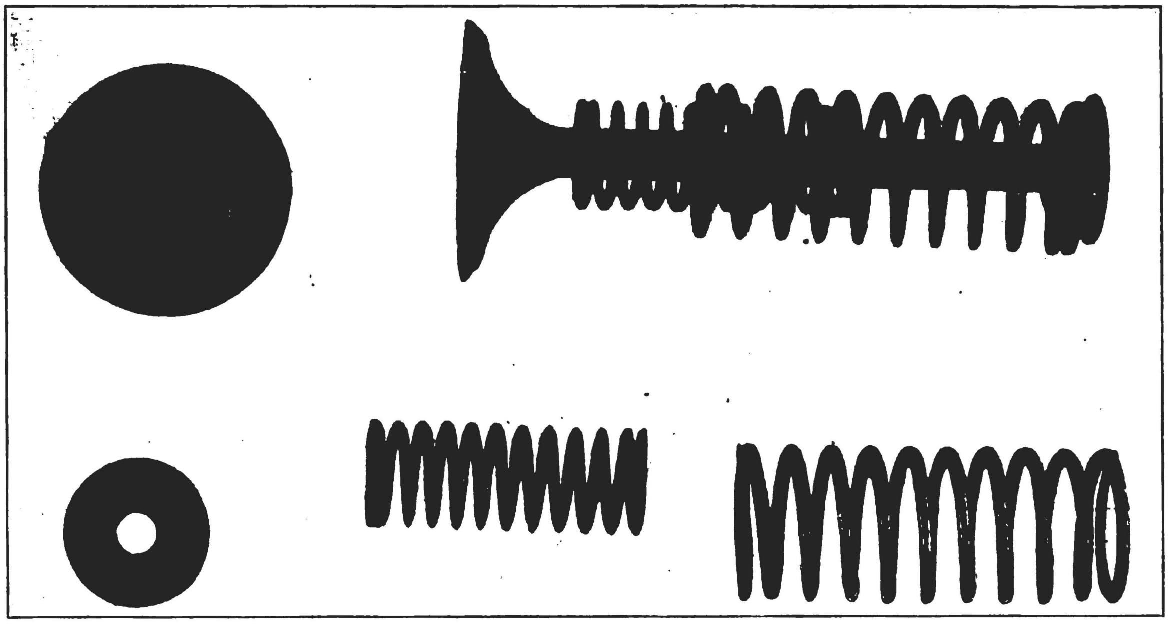

FIG. 12.—Valves and valve springs.

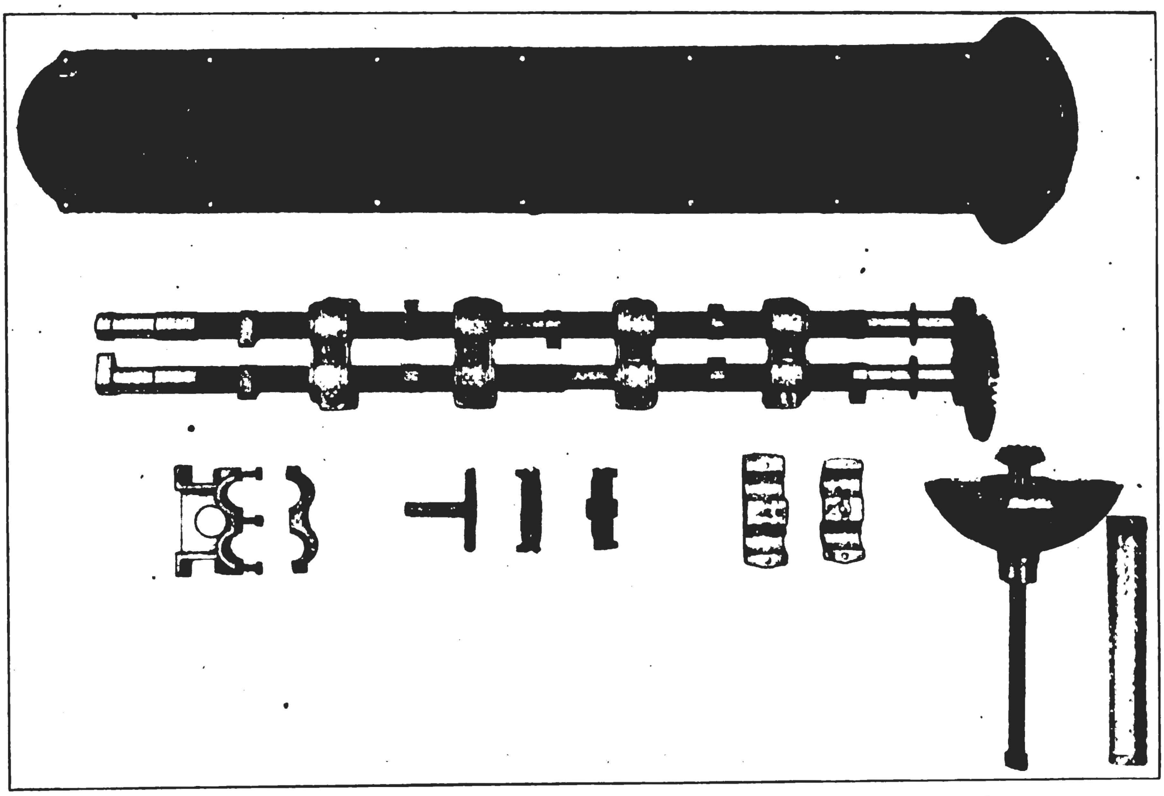

FIG. 13.—Valve gear.

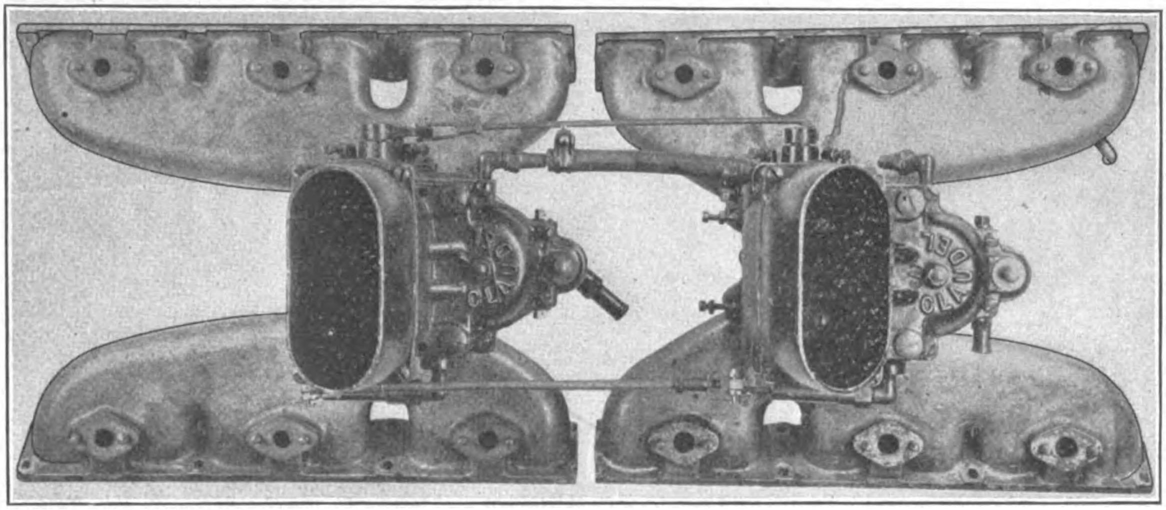

FIG. 14.—Carburetors and intake headers.

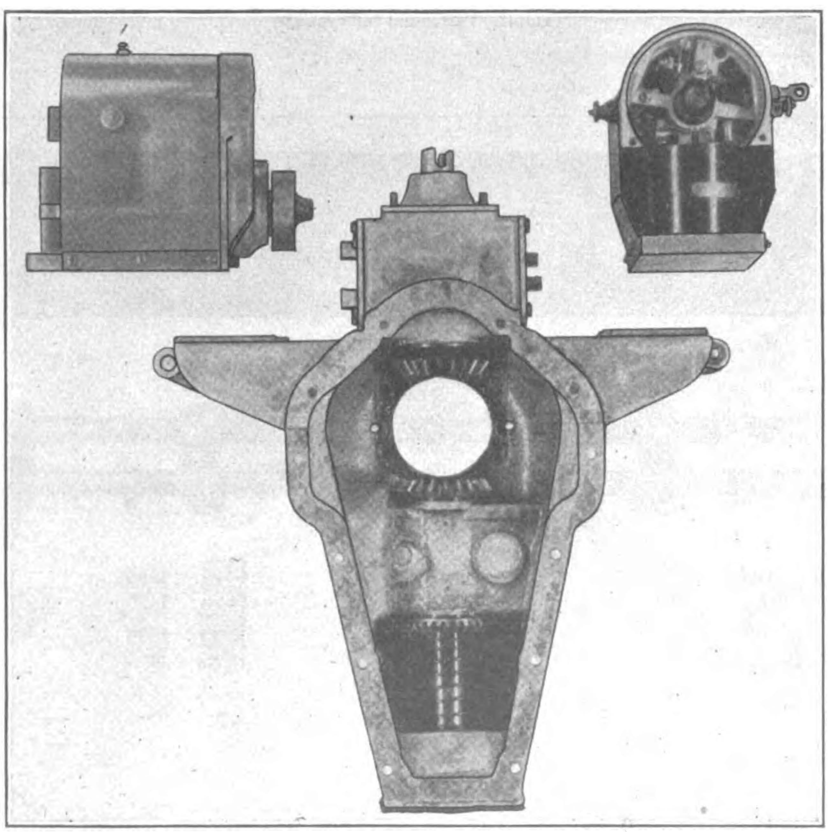

FIG. 15.—Drive gear train housing and magnetos.

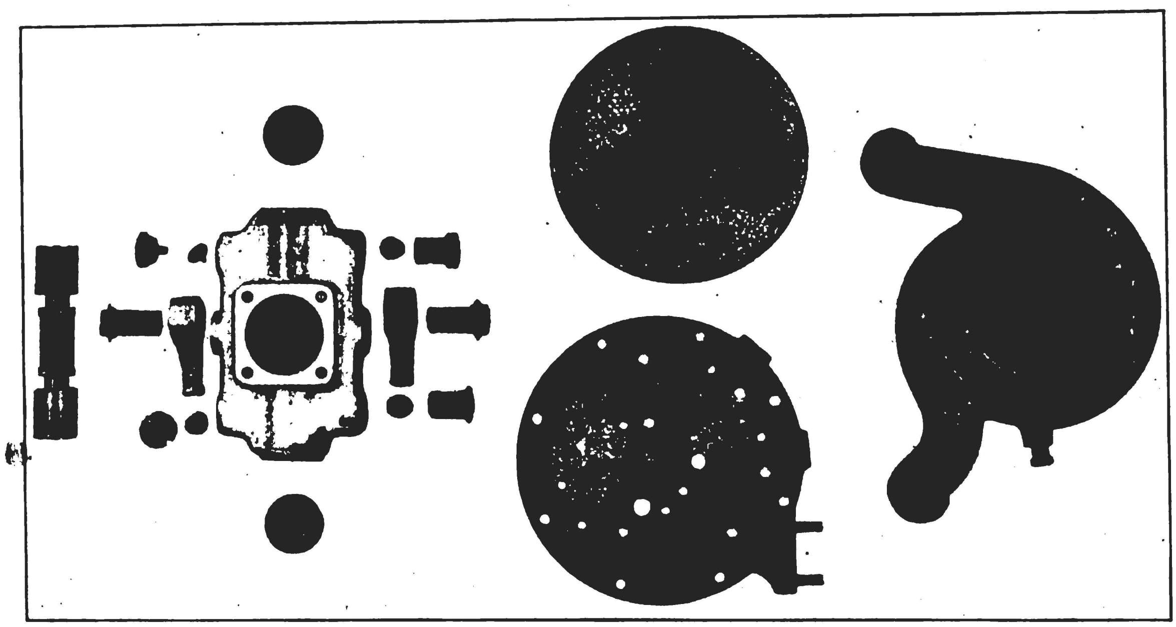

FIG. 16.—Oil pump, water pump, and gasoline pump.

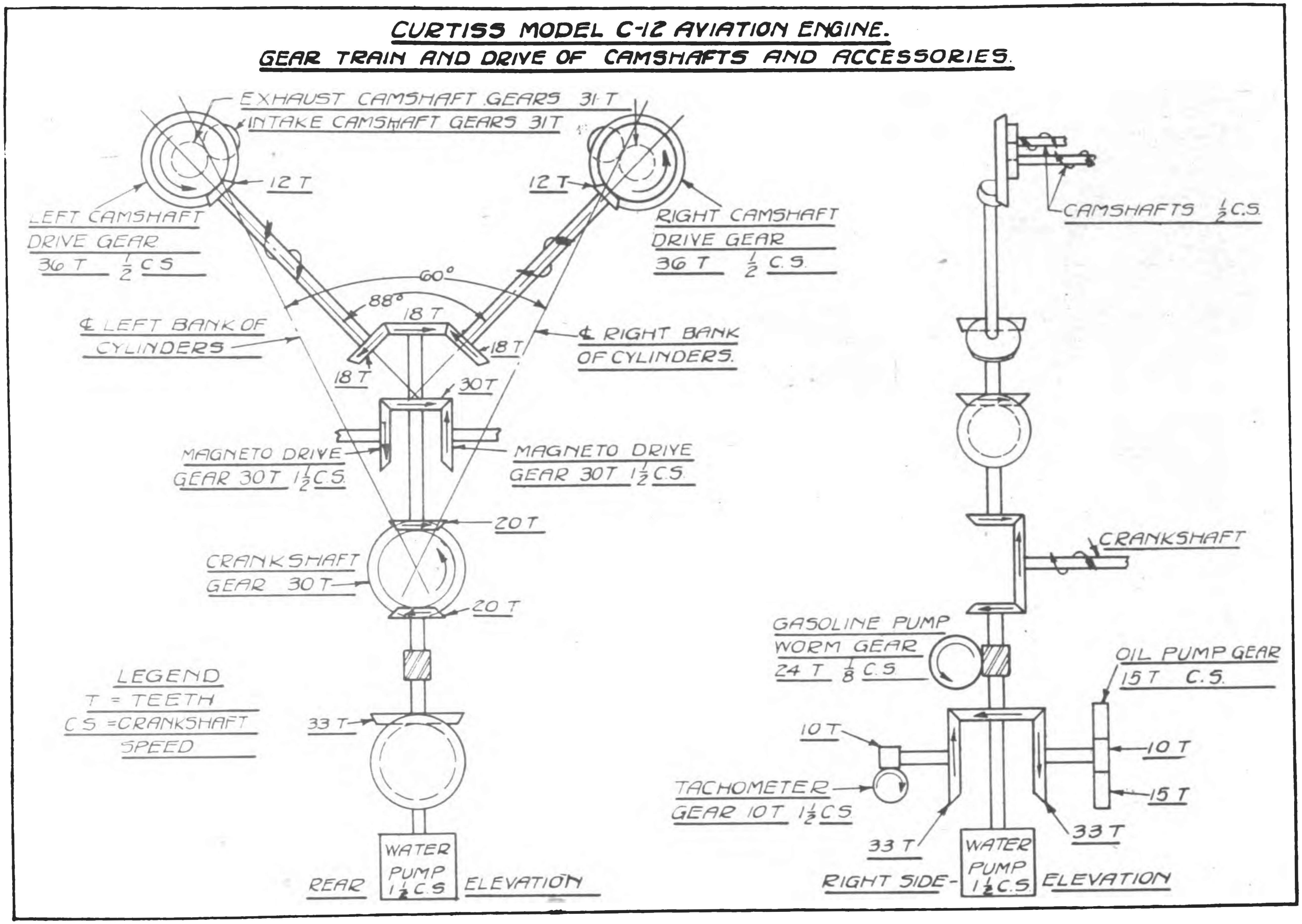
CURTISS MODEL C-12 AVIATION ENGINE.
GEAR TRAIN AND DRIVE OF CAMSHAFTS AND ACCESSORIES.
EXHAUST CAMSHAFT GEARS 31 T
INTAKE CAMSHAFT GEARS 31 T
12 T
12 T
LEFT CAMSHAFT DRIVE GEAR 36 T 1/2 C.S.
RIGHT CAMSHAFT DRIVE GEAR 36 T 1/2 C.S.
60°
88°
18 T
18 T
18 T
℄ LEFT BANK OF CYLINDERS
℄ RIGHT BANK OF CYLINDERS
30 T
MAGNETO DRIVE GEAR 30 T 1 1/2 C.S.
MAGNETO DRIVE GEAR 30 T 1 1/2 C.S.
20 T
CRANKSHAFT GEAR 30 T
20 T
LEGEND
T = TEETH
C.S. = CRANKSHAFT SPEED
33 T
WATER PUMP 1 1/2 C.S.
REAR ELEVATION
CAMSHAFTS 1/2 C.S.
CRANKSHAFT
GASOLINE PUMP WORM GEAR 24 T 1/8 C.S.
OIL PUMP GEAR 15 T C.S.
10 T
10 T
15 T
TACHOMETER GEAR 10 T 1 1/2 C.S.
33 T
33 T
WATER PUMP 1 1/2 C.S.
RIGHT SIDE-ELEVATION

FIG. 17.

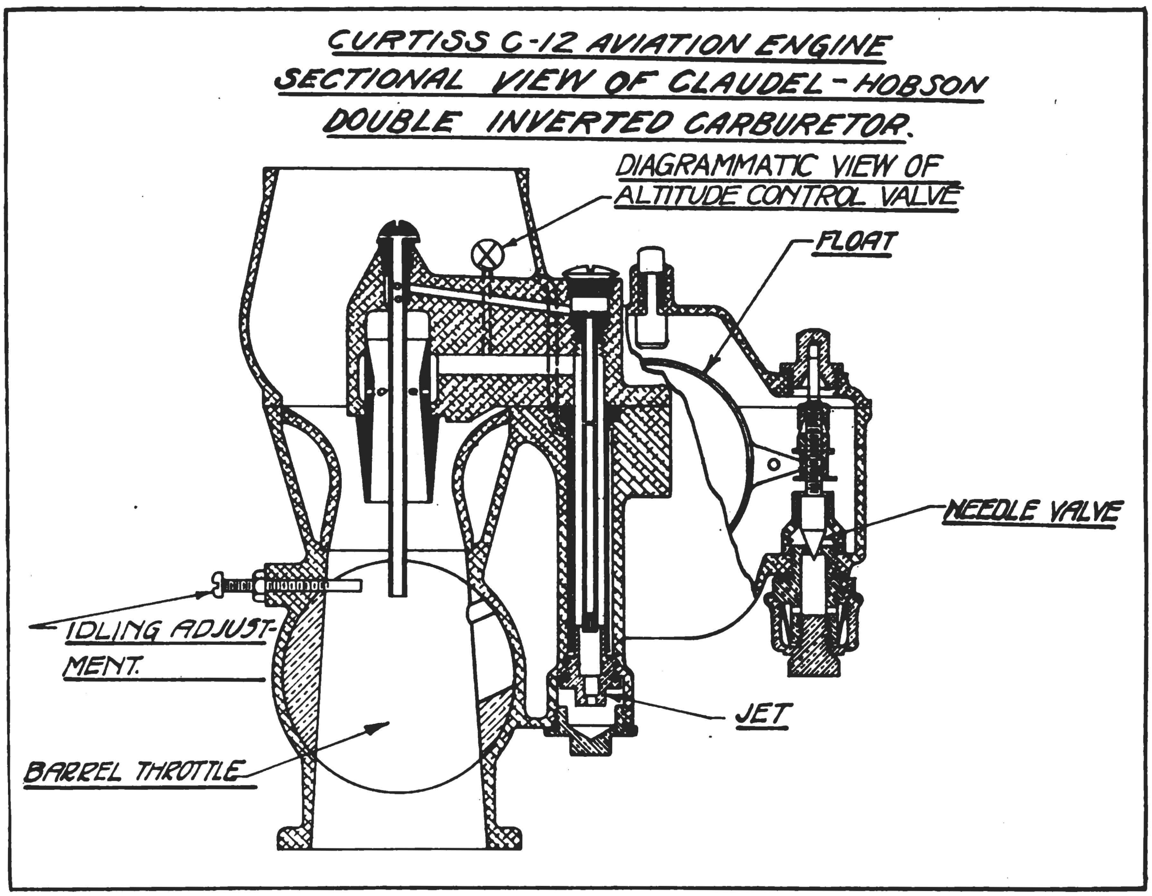
CURTISS C-12 AVIATION ENGINE
SECTIONAL VIEW OF CLAUDEL-HOBSON
DOUBLE INVERTED CARBURETOR.
DIAGRAMMATIC VIEW OF
ALTITUDE CONTROL VALVE
FLOAT
NEEDLE VALVE
IDLING ADJUST-
MENT.
JET
BARREL THROTTLE

Fig. 18.

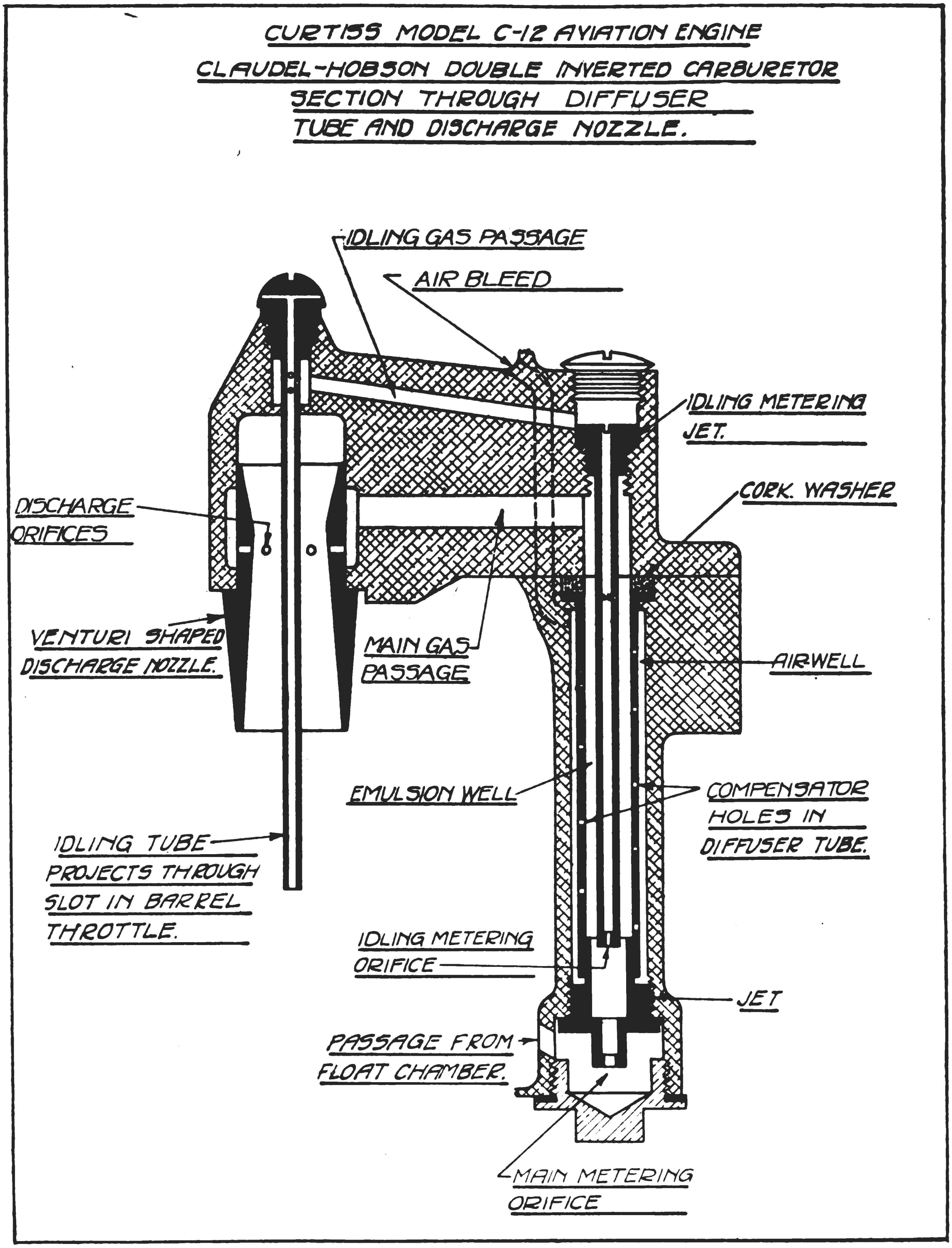
CURTISS MODEL C-12 AVIATION ENGINE
CLAUDEL-HOBSON DOUBLE INVERTED CARBURETOR
SECTION THROUGH DIFFUSER
TUBE AND DISCHARGE NOZZLE.
IDLING GAS PASSAGE
AIR BLEED
IDLING METERING JET.
CORK. WASHER
DISCHARGE ORIFICES
VENTURI SHAPED DISCHARGE NOZZLE.
MAIN GAS PASSAGE
AIRWELL
EMULSION WELL
COMPENSATOR HOLES IN DIFFUSER TUBE.
IDLING TUBE PROJECTS THROUGH SLOT IN BARREL THROTTLE.
IDLING METERING ORIFICE
JET
PASSAGE FROM FLOAT CHAMBER.
MAIN METERING ORIFICE

FIG. 19

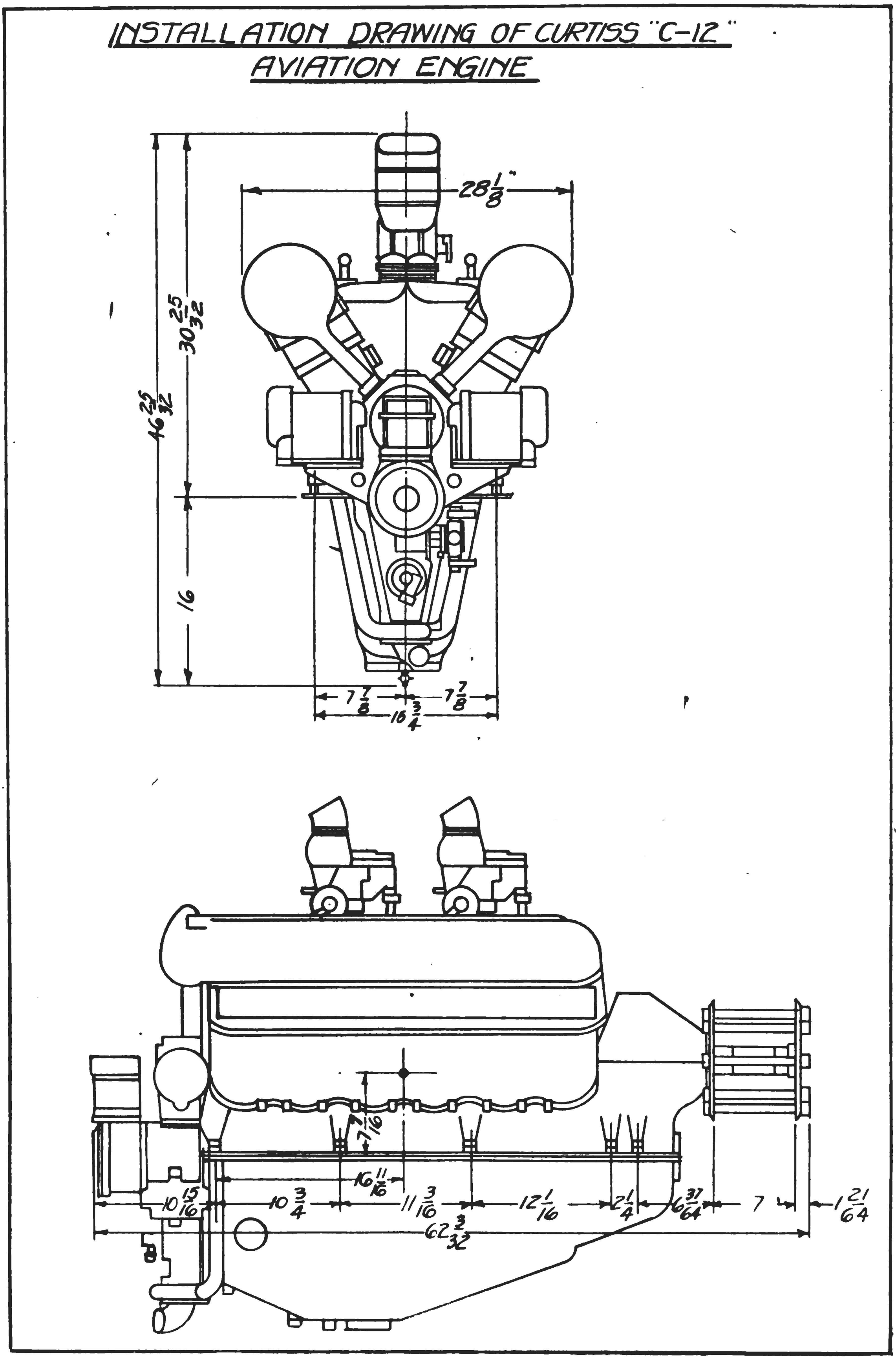
INSTALLATION DRAWING OF CURTISS "C-12"
AVIATION ENGINE
28 1/8"
30 25/32
46 25/32
16
7 7/8
7 7/8
16 3/4
7 1/16
16 11/16
10 15/16
10 3/4
11 3/16
12 1/16
2 1/4
6 37/64
7
1 21/64
62 3/32

FIG. 20.

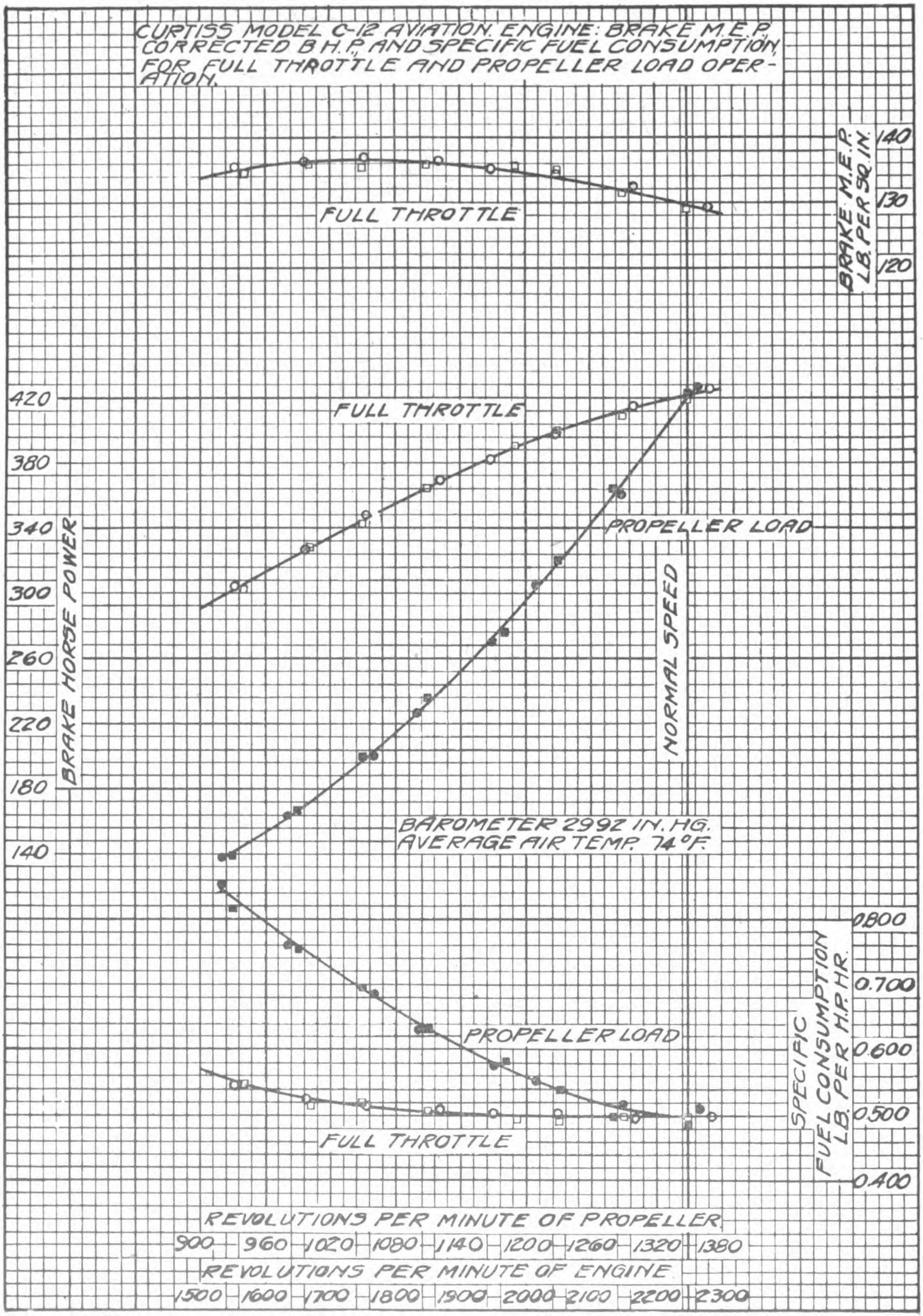
CURTISS MODEL C-12 AVIATION ENGINE: BRAKE M.E.P. CORRECTED B.H.P. AND SPECIFIC FUEL CONSUMPTION FOR FULL THROTTLE AND PROPELLER LOAD OPERATION.
BRAKE M.E.P. LB. PER SQ. IN.
140
130
120
FULL THROTTLE
FULL THROTTLE
PROPELLER LOAD
NORMAL SPEED
BRAKE HORSE POWER
420
380
340
300
260
220
180
140
BAROMETER 29.92 IN. HG.
AVERAGE AIR TEMP. 74°F.
PROPELLER LOAD
FULL THROTTLE
SPECIFIC FUEL CONSUMPTION LB. PER H.P. HR.
0.800
0.700
0.600
0.500
0.400
REVOLUTIONS PER MINUTE OF PROPELLER
900
960
1020
1080
1140
1200
1260
1320
1380
REVOLUTIONS PER MINUTE OF ENGINE
1500
1600
1700
1800
1900
2000
2100
2200
2300

Fig. 21.

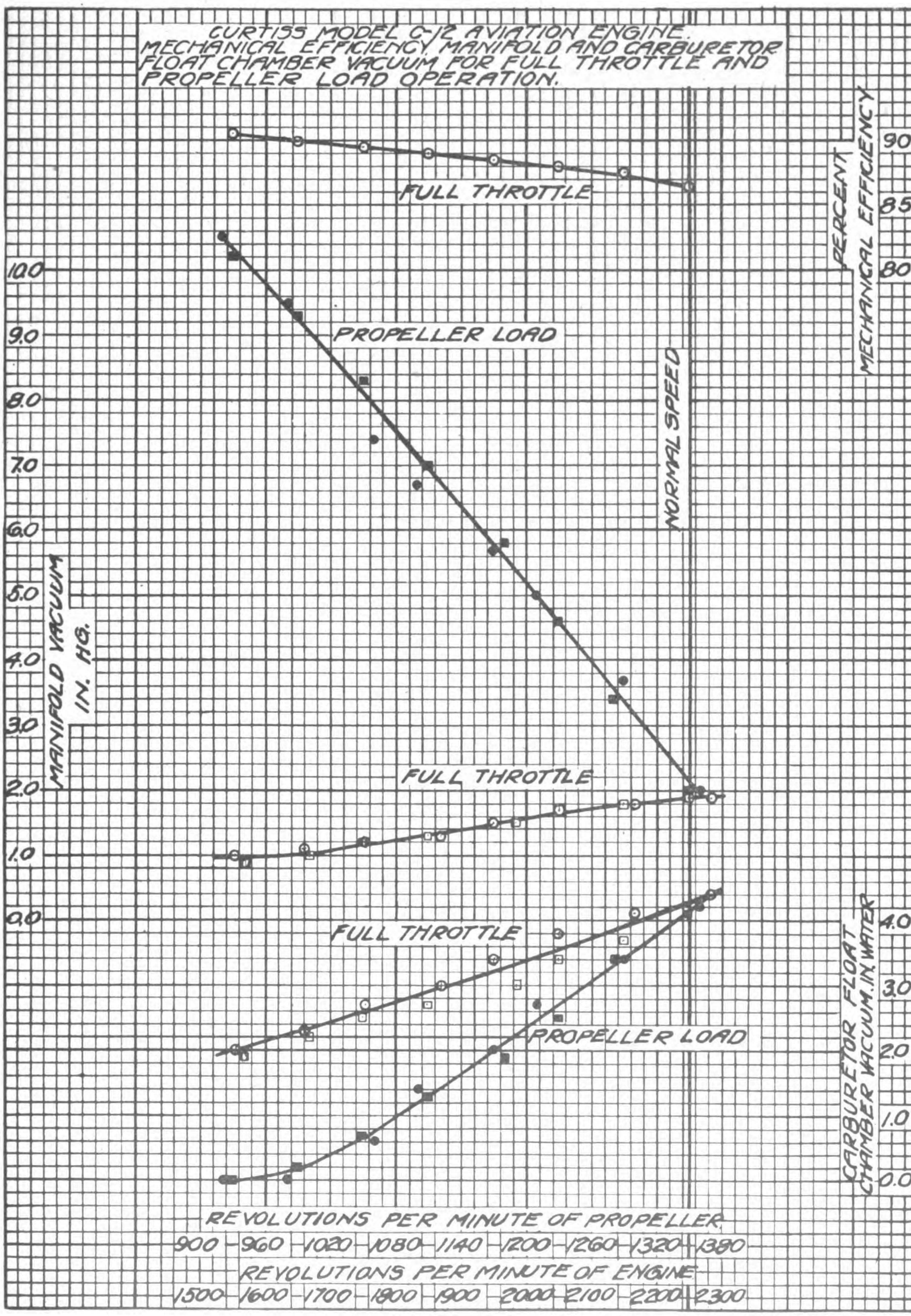
CURTISS MODEL C-12 AVIATION ENGINE.
MECHANICAL EFFICIENCY, MANIFOLD AND CARBURETOR FLOAT CHAMBER VACUUM FOR FULL THROTTLE AND PROPELLER LOAD OPERATION.
FULL THROTTLE
PROPELLER LOAD
NORMAL SPEED
FULL THROTTLE
FULL THROTTLE
PROPELLER LOAD
MANIFOLD VACUUM IN. HG.
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
PERCENT MECHANICAL EFFICIENCY
90
85
80
CARBURETOR FLOAT CHAMBER VACUUM IN. WATER
4.0
3.0
2.0
1.0
0.0
REVOLUTIONS PER MINUTE OF PROPELLER
900 960 1020 1080 1140 1200 1260 1320 1380
REVOLUTIONS PER MINUTE OF ENGINE
1500 1600 1700 1800 1900 2000 2100 2200 2300

FIG. 22.

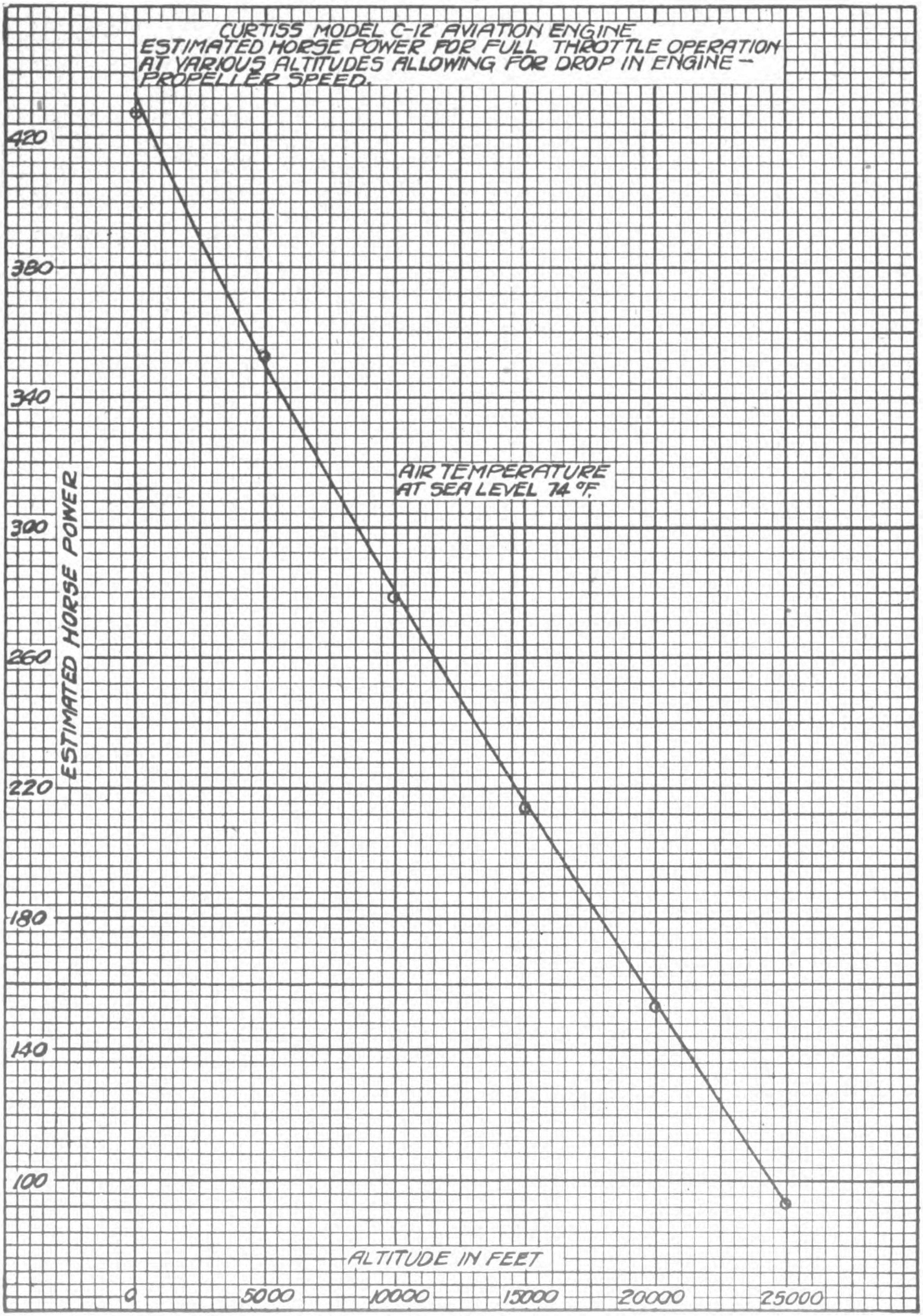
CURTISS MODEL C-12 AVIATION ENGINE
ESTIMATED HORSE POWER FOR FULL THROTTLE OPERATION AT VARIOUS ALTITUDES ALLOWING FOR DROP IN ENGINE-PROPELLER SPEED.
AIR TEMPERATURE AT SEA LEVEL 74 °F.
ESTIMATED HORSE POWER
420
380
340
300
260
220
180
140
100
ALTITUDE IN FEET
0
5000
10000
15000
20000
25000

FIG. 23.

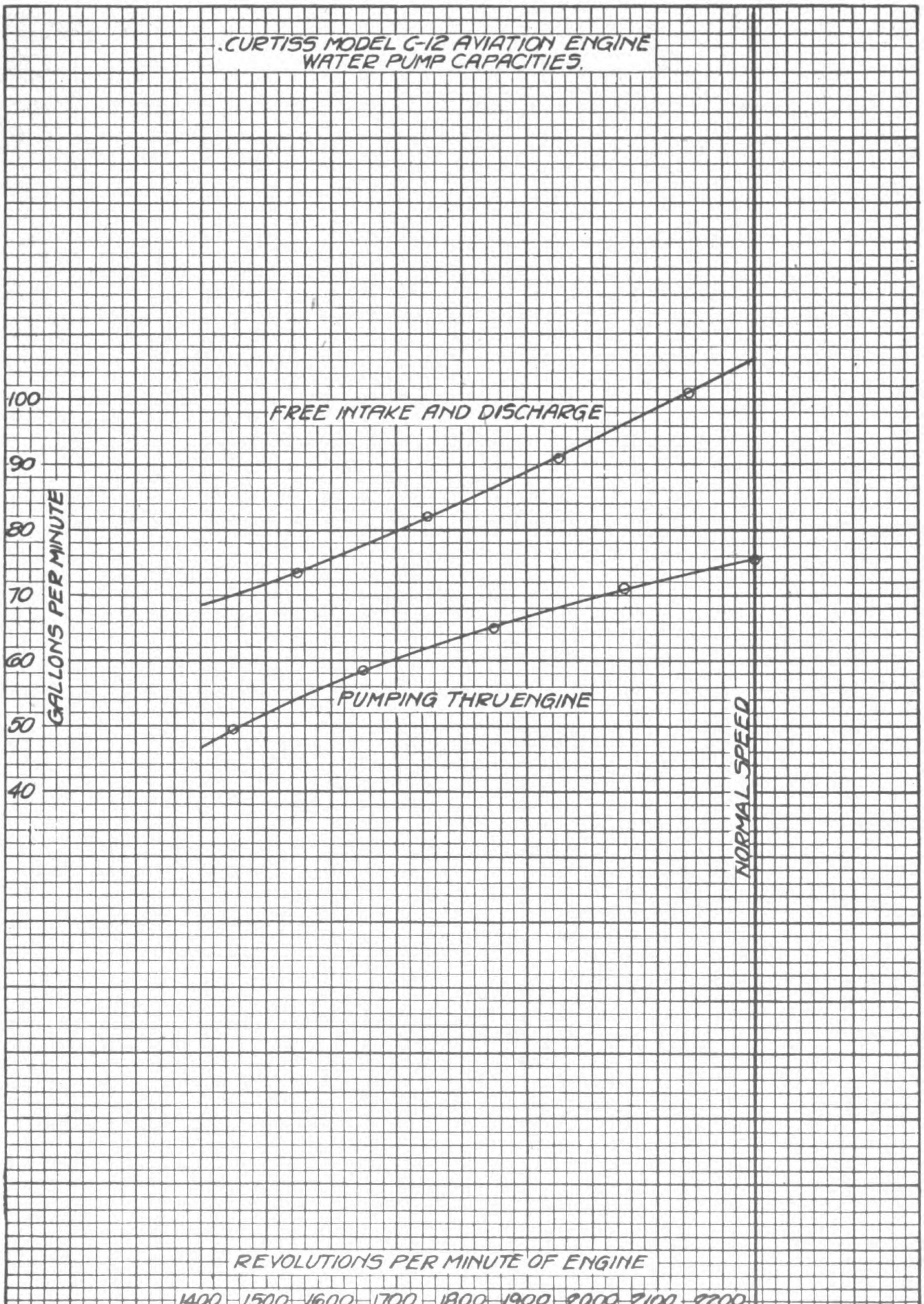
.CURTISS MODEL C-12 AVIATION ENGINE
WATER PUMP CAPACITIES.
FREE INTAKE AND DISCHARGE
PUMPING THRU ENGINE
NORMAL SPEED
GALLONS PER MINUTE
100
90
80
70
60
50
40
REVOLUTIONS PER MINUTE OF ENGINE
1400
1500
1600
1700
1800
1900
2000
2100
2200

FIG. 24.